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LACNOR FIELD STUDY

The results of a One Year Field Monitoring Program prepared for:

The National Uranium Tailings Program
Canada Centre for Mineral and Energy Technology
Energy, Mines and Resources Canada
555 Booth Street
Ottawa, Ontario
K1A 0G1

by

Golder Associates
3151 Wharton Way
Mississauga, Ontario
L4X 1B6

SENES Consultants
499 McNicoll Avenue
Willowdale, Ontario
M2H 2C9

BEAK Consultants
6870 Goreway Drive
Mississauga, Ontario
L4V 1P1

Cumming-Cockburn
145 Sparks Avenue
Willowdale, Ontario
M2H 2S5

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EXECUTIVE SUMMARY

The Site

Mining operations to recover uranium ore were carried out at the Lacnor mine, located east of Elliot Lake, for three years in the late 1950's until the mine ceased operations in December 1959. The pyritic tailings, which were neutralized prior to discharge, were deposited in a small swampy valley located east of the mill. The southeast end of the valley was dammed to form the impoundment, which now contains an estimated 2.7 million tonnes of tailings.

The Field Study

In December 1984, Golder Associates, SENES Consultants Limited, BEAK Consultants and Cumming-Cockburn & Associates Limited were awarded a contract by the National Uranium Tailings Program to carry out a field study at the Lacnor uranium tailings area. The objective of the field program was to design and operate a sampling program to collect chemical, physical and biological data to characterize the Lacnor tailings area and its environs. The field study required the sampling of tailings solids, subtailings soil and rock, the surrounding soil and rock, tailings porewater, surface water, the measurement of surface water runoff, the gathering of meteorological and atmospheric data, and a biological assessment of the site.

The field program was intended to be a data gathering exercise and interpretation of the results was specifically excluded from the terms of reference for the study.

Field investigations were carried out from December 1984 up to the end of October 1985 when monitoring was discontinued. An overview of the program and the data collected are provided in this summary report while the detailed methodology, quality assurance and results for each component of the overall investigation were compiled into a series of four separate data appendices. A fifth appendix contains a description of the laboratory facilities, analytical methods and internal quality assurance programs of the different laboratories.

Geohydrology and Geochemistry

Some limited geotechnical testing of the surface of the tailings area and installation of several monitoring wells had been carried out prior to this field program, however the work did not include detailed investigations of the kind carried out at several other Elliot Lake basins.

As part of the 1985 field program, gradation analyses of surficial tailings samples obtained during an initial site reconnaissance confirmed that the tailings varied from coarse sand tailings at the western end and northern half of the basin to finer predominantly silt sized tailings in the eastern and southeastern parts of the basin.

Boreholes were put down at five locations across the tailings area. Between 8 m and 15 m of tailings were encountered at the five borehole locations across the tailings, overlying variable deposits of till, peat and sands, silts and gravels. The results of in-situ hydraulic conductivity tests in the tailings varied between 2 x 10^{-6} cm/s and 5 x 10^{-4} cm/s, but these were lower than those determined from constant head laboratory permeameter tests. The sand and gravel below the tailings was more pervious. The permeability of the bedrock ranged from low (3 x 10^{-7} cm/s) to relatively high (3 x 10^{-3} cm/s).

Soluble sulfur, which likely was present in the tailings as calcium sulphate, occurred at concentrations as high as 5 per cent. Measured concentrations of reduced sulphur, which was assumed to exist as pyrite, were less than 3 per cent. Uranium concentrations in the tailings solids ranged from 10 to 80 ppm. Radium-226 and Thorium-230 concentrations ranged from 0.6 to approximately 12.5 Bq/g.

Off-tailings boreholes were drilled in two valleys south of the tailings area. These valleys were considered to contain the major potential groundwater seepage pathways exiting from the tailings area.

Sampling of selected monitoring wells indicated that the chemical characteristics of the porewater existing in the Lacnor tailings basin in 1985 had been influenced by the initial composition of the process water and solids originally discharged to the basin and the low pH recharge water that had developed as a consequence of pyrite oxidation at shallow depths within the tailings since their deposition. The porewater was generally acidic at shallow depths and moderately acidic to neutral at depths of more than several metres within the tailings.

The pH increased and electrical conductance decreased with depth in the porewater in the coarse tailings in the western section of the basin. In the interlayered fine and coarse tailings in the east and southeastern portions of the tailings area, the profiles of pH and electrical conductance in the porewater were not depth dependent. However, these trends may have been influenced by the unusual occurrence of ponded surface water during the spring and early summer of 1985 when the exit for run-off from the Lacnor pond was temporarily dammed.

The concentrations of the primary dissolved constituents in the porewater such as sulfate, iron and the major ions and the concentrations of metals within the porewater were variable across the tailings, but in many cases, the peak concentrations were associated with low pH. With the exception of uranium, which exhibited a trend of increased concentrations with depth, the concentrations of radiological parameters in the porewater typically did not vary with depth in the tailings.

The monitoring program indicated that the chemistry of the groundwater in the sub-tailings overburden and, to a lesser extent, the sub-tailings bedrock, had been influenced by the tailings porewater. However, impacts of the tailings on the groundwater chemistry in the bedrock piezometers at off-tailings monitoring stations were generally very low.

Meteorology, Air Quality and Radioactivity

Meteorological conditions were monitored at three locations. The main meteorological station was located on the Lacnor tailings, where wind speed and direction (at a height of 10 m), temperature, solar radiation, precipitation and evaporation were monitored. Wind speed and direction were also monitored on the Nordic tailings area to the south, while temperature, relative humidity, barometer pressure and precipitation were monitored in the Town of Elliot Lake.

Mean daily temperatures ranged from -12°C in January to 20°C in July. The total amount of precipitation between 19 December 1984 and 31 October 1985 was 695 mm. The mean monthly evaporation between 1 May and 31 October 1985 was 106 mm.

Air quality was monitored at eight locations for dustfall and at two locations for suspended particulate matter (SPM). Monthly dustfall samples were analyzed to determine the organic/mineral and soluble/insoluble fractions. Three-month composites of the inorganic fractions were prepared and analyzed for various radionuclides. Samples from four sites on the edge of the tailings were analyzed for Radium, Thorium-228, 230, 232, Lead-210 and Uranium. The four off-tailings samples were analyzed for only Radium, Thorium-230 and Uranium.

The overall average dustfall level measured during the January to October period was 1.4 g/m^2/30 days. Organic contents ranged from 39 to 95%. Lead-210 activity per gram was the highest of the five parameters for the four on-tailings sites and ranged from 0.05 to 1.10 Bq/g. For the four off-tailings sites Radium-226 activity per gram was equal to or higher than Thorium-230, and ranged from 0.004 to 0.169 Bq/g. Uranium levels at the eight sites averaged 0.32 ug/g.

Radioactivity measurements consisted of ambient radon monitoring, radon exhalation testing and surface gamma radiation surveys.

Ambient radon levels were measured at twelve locations in the vicinity of the tailings. Between the edge of the tailings and 100 m from the tailings the radon levels ranged from less than 0.002 to 0.040 Bq/L. Radon exhalation rates from the surface of the tailings were determined for various tailings conditions. The exhalation rates ranged from a low of 0.0089 Bq/m^2/s in March on a dry, hard sandy tailings surface to 6.67 Bq/m^2/s in June on a damp non-vegetated surface. A comprehensive surface gamma radiation survey of the tailings area was carried out on a 30 m X 30 m grid. The contact gamma levels ranged from a low of 30 uR/h to a high of 1100 uR/h. The higher gamma levels (> 500 uR/h) were found on the eastern third of the site.

Surface Water

Although there is no treatment plant for run-off water from the Lacnor tailings area within the Lacnor basin, tailings overflow from Lacnor drains to Rio Algom's Nordic tailings areas. Overflow from the Nordic tailings area is treated prior to discharge into the Serpent River Watershed. Pond effluent from the Lacnor basin has been monitored on a regular basis by Rio Algom since 1979.

For this field study three weirs were constructed to monitor surface flow from the Lacnor tailings area. One was installed on Lacnor Creek to monitor outflow from the tailings pond, while two were located on creeks to monitor seepage. Continuous discharge monitoring was carried out between 23 March and 3 November 1985. Flow from the Lacnor pond was severely curtailed during the spring run-off when an earth-fill dam had to be constructed in Lacnor Creek to reduce flooding downstream on the Nordic tailings area where a decant tower had collapsed.

Mean monthly flows at the pond outlet varied significantly from 0.4 L/s in July to 124 L/s, in April. Although mean monthly seepage rates ranged from 0.2 to 1.2 L/s and 1.2 to 12.3 L/s at the other two sites during the study period, the seepage rates were relatively constant during the period when the earth-fill dam was not in place.

Surface water samples were collected on a routine basis from the streams at the three weir locations during the period January through to October 1985. The surface waters were found to be acidic with iron, calcium, aluminum and manganese being the dominant cations, and concentrations being in the tens to hundreds of mg/L range. Sulphate was the most abundant anion, ranging from several hundred to several thousands of mg/L in concentration. Redox reactions involving iron appear to be the dominant control on pH in the streams. The iron would appear to result from pyrite oxidation, the calcium and sulphate from gypsum dissolution, and the aluminum and manganese from acid attack of aluminosilicate minerals in the tailings. The other twenty or so anions and cations measured were present in concentrations below the mg/L level. The radionuclides in both the uranium and natural thorium decay series showed considerable variability in their surface water concentrations. Natural uranium concentrations ranged from about 0.1 to 0.6 mg/L (1.23 to 7.38 Bq/L), while natural thorium ranged from 0.2 to 2.5 mg/L (0.1 to 5.0 Bq/L), probably reflecting a higher sensitivity of thorium solubility to pH. The concentrations of decay products with the exception of Th-230 were within the range of secular equilibrium as set by the parent uranium and thorium. The data suggest pH is the factor which has the most profound influence on the levels of radionuclides and trace elements in the streams draining the tailings. The pH which was observed to range from 2.8 to 5.4 is sufficiently low to preclude the presence of any fish in the streams draining the site.

Biology

A review was conducted of regional studies of biota. Data on biological concentrations of metals or radionuclides and on the importance of various biological pathways in the Elliot Lake region were summarized. On the tailings themselves, the biological studies focused principally on the microbial populations in the tailings and upon the vegetation recolonizing the tailings. Tailings solids were analyzed for both pyrite oxidizing bacteria and sulphate reducing bacteria. No distinct spatial trends could be discerned for bacterial counts with variability as great as 10^6 times being found between successive layers in the tailings. Six vegetative communities on the surface of the tailings were investigated for biomass per unit area and radionuclide and trace element uptake based on tailings-soil concentrations. A wide range in plant biomass was found on the tailings surface reflecting a high variability in surface soil conditions. All of the vegetation communities showed bioexclusion of radionuclides with levels in the plant tissues being lower than in the supporting soils. Most of the major and trace elements also showed a bioexclusion with some bioconcentration being noted for essential trace elements such as selenium, nickel and zinc, which were present at very low concentrations in the tailings.

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1.0 Introduction

1.1 Study Overview and Objectives

Uranium mining and milling operations began in the Northwest Territories in 1943 and have been conducted in Ontario and northern Saskatchewan since the mid 1950's. Since that time, 19 uranium mining operations have produced more than 160 million tonnes of tailings. Of this total, approximately 150 million tonnes have been deposited in a variety of surface impoundments covering a total of 635 ha, with the remainder deposited underwater in lakes or used as mine backfill. The bulk of the uranium mine tailings, (135 million tonnes), are located in the Elliot Lake area of Ontario.

The National Uranium Tailings Program (NUTP) was announced in September, 1982. The main objective of the NUTP is to provide a scientifically credible information base which will assist government regulatory agencies and the uranium industry in making knowledgeable decisions and in establishing criteria for the long-term protection of the environment and human health.

The NUTP comprises three components: modelling, measurement and disposal technology. The objectives of the measurement component of the Program are to provide basic data needed for mathematical model building, calibration and validation. It included two major field investigations of inactive uranium tailings sites, one in Ontario at Elliot Lake (Lacnor) and one in Saskatchewan (Gunnar).

In December, 1984, Golder Associates, SENES Consultants Limited, BEAK Consultants and Cumming-Cockburn & Associates Limited were awarded a contract by the National Uranium Tailings Program to carry out the field study at the Lacnor uranium tailings area in Elliot Lake, Ontario. The intent of the project, as set out in the terms of reference, was:

> "The design and operation of a sampling program, incorporating chemical, physical and biological data that will be used to

characterize the Lacnor tailings and environs, and which will provide raw data for the study of processes involving tailings constituents and their pathways".

The field study required the design of a sampling plan; the sampling of tailings solids, subtailings soil and rock, the surrounding soil and rock, tailings porewater, surface water; the measurement of surface water runoff; the gathering of atmospheric data; and a biological assessment of the site. This was intended to be a data gathering exercise and interpretation of the results was specifically excluded from the terms of reference for the study.

Monenco Analytical Laboratories of Calgary, Alberta, and Chemex Labs Ltd. of Vancouver, British Columbia, were retained for radiological analyses on tailings solids, groundwater, dust samples and vegetation. Barringer Magenta Limited of Rexdale, Ontario, and BEAK Analytical Services of Mississauga, Ontario, were retained for other chemical testing. All geotechnical testing was carried out at Golder Associates' Mississauga Laboratory. Bacterial analyses were performed at the Microbiology Laboratory, University of Waterloo.

There are five appendices to this summary report, each published separately. They are:

Appendix 1	Geohydrology and Geochemistry
Appendix 2	Meteorology, Air Quality and Radioactivity
Appendix 3	Surface Water Studies
Appendix 4	Biology
Appendix 5	Laboratory Facilities and Chemical Methods

The first four Appendices contain the detailed methodology, quality assurance, and results for each component of the overall program. Appendix 5 contains a description of the laboratory facilities, analytical methods and internal quality assurance program of the different laboratories.

Although carried out as an integrated study, the various members of the study team were responsible for the following tasks:

Golder Associates -	overall coordination and management, geohydrology and geochemistry, including geology, tailings solids, sub-tailings overburden and bedrock, off-tailings bedrock, tailings porewater and groundwater.
SENES Consultants -	meteorology, air quality, field work coordination, health and safety, radon and radon flux measurements, and surface gamma radiation measurements.
BEAK Consultants -	surface water quality, biological assessment, preparation of report on laboratory facilities and analytical methods.
Cumming-Cockburn -	physical aspects of surface water flow, snow course measurements.

1.2. Outline of Summary Report

This summary report is organized into the following sections:

2. Background, provides a summary of the history of the site, including mining and milling at the Lacnor complex and the deposition of tailings in the Lacnor tailings basin between 1957 and 1959. The topography and regional geology of the area are discussed. This is followed by a review of background data from the site (or, where not available, a general review of Elliot Lake data) for geohydrology and geochemistry, meteorology and air quality, radioactivity, surface water and biology.

3. Geohydrology and Geochemistry, summarizes the geological reconnaissance of the basin, the results of borehole drilling

through the tailings into the underlying overburden and bedrock, characterization tests (grain size, water content, permeability) and chemical analyses of tailings solids, the results of off-tailings drilling in potential faults exiting from the tailings basin, and porewater and groundwater sampling.

4. Meteorology, Air Quality and Radioactivity, provides brief descriptions of these three monitoring programs and summaries of the data obtained. Meteorological parameters monitored were wind speed, wind direction, temperature, relative humidity, barometric pressure, solar radiation, precipitation, snow course measurements and class A pan evaporation; air quality parameters measured were dustfall and suspended particulate matter; radioactivity pertains to measurements of ambient radon, radon flux from the tailings surface and surface gamma radiation levels over the tailings area.

5. Surface Water Studies, presents the results of the surface water discharge monitoring program and the chemical analysis results of the surface water streams sampled. Monitoring locations, sampling procedures, equipment and calibration methodology are also discussed.

6. Biology, provides a brief overview of the biological data collection component; a brief summary of the currently available regional historical biological data; and details of the field program with specific reference to bacteria, vegetation, soils and wildlife.

1.3. Chronology of Events

The Lacnor study was formally initiated on November 1, 1984 by telex from DSS. A detailed sampling plan had been submitted with the proposal for the Lacnor study. This enabled work to be initiated speedily prior to the onset of extremely cold weather.

A geological reconnaissance of the site was carried out November 13-16, 1984, immediately prior to snowfall.

Design of the weirs for surface water runoff measurements was completed in early December and tenders were requested by late December, 1984. Construction of the weirs was initiated during January, 1985, and completed by February 15, 1985. The volume of surface water runoff was monitored on a continuous basis until the end of October, 1985. During this period water samples were collected on a routine basis.

Meteorological and air quality monitoring equipment were organized during November and December, 1984. The meteorological station was put in operation by December 20, 1984. The dustfall jars, radon monitors and suspended particulate matter samplers were put into operation during January, 1985.

A sampling plan was submitted by the study team to the National Uranium Tailings Program on January 28, 1985.

The on-tailings geohydrological investigation was carried out between March 11, and April 4, 1985, with boreholes drilled through the tailings and monitoring wells installed.

On April 24, 1985, during the period of peak spring runoff, Rio Algom plugged the flow leaving the Lacnor pond to help alleviate a problem further downstream. Due to this blockage, water backed up onto the tailings. The temporary dam was removed June 17, 1985.

During early June, drilling of two potential bedrock fault/fracture zones exiting the tailings basin was completed and monitoring wells installed. The first set of parameter and groundwater samples were collected between June 11 and 14, 1985 after the pond had begun to recede.

A surface gamma survey of the tailings was initiated in mid June and completed by mid July after the surface flooding had receded.

The biology field program was initiated during the last week of July and completed in early August.

The second set of porewater and groundwater samples was collected between August 19 and 21, 1985.

During the first week of November, 1985, monitoring equipment for the meteorological, air quality, radioactivity and surface water flow components were removed.

Initial draft reports were submitted during December, 1985 and January, 1986. Following this, additional inter-laboratory comparisons were carried out. These results were received during March, 1986 and the final report then revised and submitted.

2.0 BACKGROUND

2.1 Site History

During the course of the study, information on the mining, milling and deposition of tailings at Lacnor was provided by Rio Algom Limited. Supplementary data from other sources are noted where appropriate, but such data were limited in extent.

2.1.1 Mining and Milling

The Lacnor mine is located approximately 5km (3 mi) east of Elliot Lake. Mining operations at Lacnor were carried out from January 1957 to December 1959. According to OWRC (1966), the Lacnor mine was formerly known as Lake Nordic Uranium Mines Limited. It was the first mine in Elliot Lake to close down.

Ore deposits in the Elliot Lake area are large, relatively low-grade deposits with uranium and thorium occurring in brannerite, uraninite and monazite minerals. The principal accessory metallic mineral in the Elliot Lake ores is pyrite (iron sulfide). The average grade of ore at Lacnor during 1958 was 0.95 kg/tonne (1.89 lb/ton), but this increased to 1.0 kg/tonne (2.0 lb/ton) during 1959.

The extraction process consisted of leaching in large rubber lined steel pachuca tanks with a double clarification process and moving bed ion exchange stage and a combined solid-liquid process for final neutralization.

The mill at the Lacnor complex was rated for 3,640 tonnes/day (4,000 tons/day) (4,500 tons/day according to OWRC, 1966), but because Lacnor only produced 3,450 tonnes/day (3,800 tons/day), additional ore was received from Buckles Mine. The first drum of U_3O_8 was produced on 22 November 1957. Up to November 1959, Lacnor had shipped more than 17,000 drums of U_3O_8, each drum weighing about 125 kg (275 lb). OWRC (1966) suggested that milling operations ceased in July, 1960. This is in agreement with MacLaren (1977) who indicate that the Lacnor complex was closed in July, 1960.

No definitive information is available on the reagents used during processing.

2.1.2. Tailings Deposition

Very little information is available concerning the deposition of the Lacnor tailings. The basin, which is located about 600 m east of the mill, is approximately 1,200 m long along its major east-west axis and about 200 m wide in a north-south direction. The tailings area covers approximately 25 hectares (62 acres).

Examination of copies of 1957 airphotos reveal that, prior to tailings deposition, the area of the tailings basin was a valley, which was primarily tree covered. Three small ponds connected by low or marshy areas were also located within the limits of the present basin.

According to OWRC (1966), the valley was dammed at the easterly end to create the impoundment area. Information supplied by previous employees indicates that tailings were only discharged at the west end. The sole treatment during operation was pH adjustment to 8 in the mill; there was no treatment plant for runoff water from the Lacnor tailings within the Lacnor basin. However, OWRC (1966) noted that the tailings overflow from Lacnor drained to the Nordic tailings area which was receiving barium chloride treatment before it entered the Serpent River watershed.

OWRC (1966) suggested that, based on production figures, the volume of tailings waste for the Lacnor mine was estimated at 1.8 million cubic metres (63 million cubic feet) containing 0.77 kg (1.7 lb) of Radium-226. MacLaren (1977) estimated that the tailings area contained 2.7 million tonnes (3 million tons) of waste.

2.1.3. Post Deposition

No records have survived of any monitoring of the Lacnor tailings area for the period after the end of tailings deposition (1959) up to about 1977. However, in 1966 it was noted in a report by OWRC that "at present, there is little overflow from the Lacnor tailings area except in periods of heavy and/or extended rainfall and during spring runoff".

In May 1978 investigations were carried out for the vegetation of approximately 12 hectares of the Lacnor tailings.

Although some surficial/tailings samples were taken for geotechnical testing, no vegetation test plots were installed on the Lacnor area due to the access road being impassible due to frost heaving. However, based on the results of the test plots at Nordic, a limestone application rate of 7 tonnes per hectare was inferred for the Lacnor tailings area.

Monitoring of the pond effluent from the Lacnor basin has been carried out on a regular basis by Rio Algom since 1979 (see Section 2.6).

From the iron staining of the bedrock surrounding the tailings pond, it may be inferred that at some point in time in the past, the pond was lowered by some 1.5 to 2 m when a channel was cut through the bedrock for the pond effluent.

2.2 Topography

The topography of the Lacnor basin prior to the deposition of tailings was briefly discussed in Section 2.1.2. There are no known available topographic maps prior to tailings deposition.

Existing Rio Algom mapping (on an Imperial Scale) did not cover the entire basin and predated re-contouring of the surface of the tailings. During the preliminary stages of the study, maps based on Ministry of Natural Resources

(MNR) 1:10,000 scale mapping of the area with a 5 m contour interval were therefore used.

On May 22, 1985, the site was flown over as part of this study (see Figure 1) to produce new topographic mapping of the study area at a scale of 1:2,000, with a 2 m contour interval on the tailings. From this, 1:5,000 mapping of the study area with a 10 m contour interval was subsequently derived. However, it should be noted that between April 24 and 17 June 17, 1985, the outflow from the Lacnor pond was blocked by Rio Algom to reduce water flow to the downstream Nordic tailings area. For this reason, the Lacnor tailings pond was abnormally high when flown in May 1985.

2.3. Regional Geology

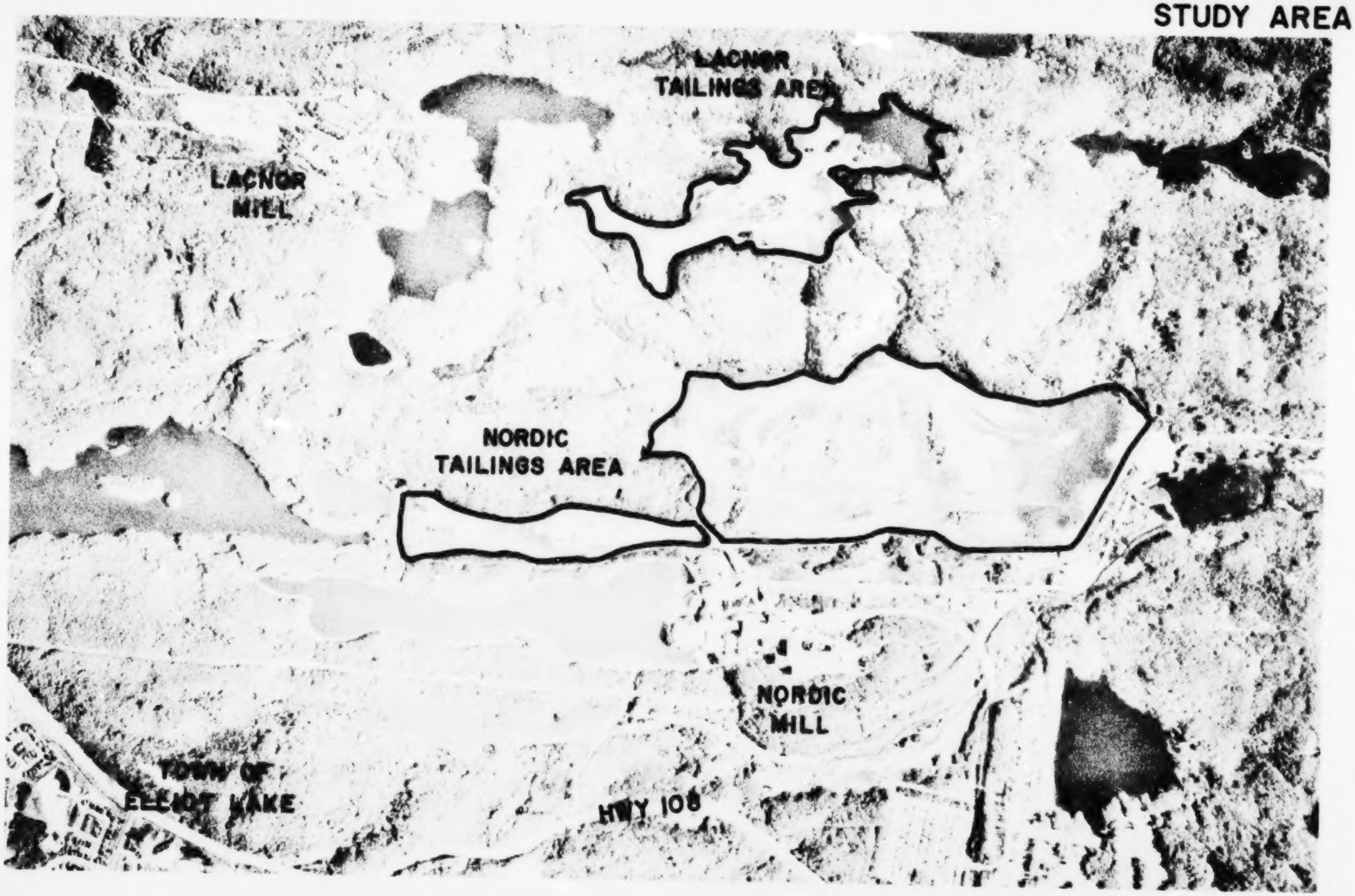
The ground surface within the Elliot Lake area is fairly characteristic of Canadian Shield terrain. It is rugged but of relatively low relief with elevation differences being generally about 30 to 60 m or less. Topographic highs consist typically of rock knolls or ridges and intervening low areas generally contain swamps, lakes or streams (Davis et al., 1979). The topography is dominantly controlled by the structural orientations in the underlying bedrock.

The underlying bedrock is largely Lower Proterozoic age metasediments comprised of quartzite, arkose, conglomerate and minor argillaceous strata. These rocks have been folded into a broad, westward plunging syncline some 8 to 10 km in width known as the Quirke Syncline (Robertson, 1968). The Lacnor Mine is located on the south limb of the syncline. The folded metasedimentary strata are cross cut by intrusive diabase sills and dykes (Nipissing Diabase) and faults (Robertson, 1968).

Regional fault structures are oriented both northwest-southeast and east-west. These features tend to occur at 5 to 6 kilometre intervals. Smaller scale faulting tends to be more intense (1 to 2 features per square kilometre) and, while generally steeply dipping, exhibit variable strike and persistence.

FIGURE 1

1985 AERIAL PHOTO
STUDY AREA


LACNOR TAILINGS AREA
LACNOR MILL
NORDIC TAILINGS AREA
NORDIC MILL
TOWN OF ELLIOT LAKE
HWY 108

Intruded diabase dykes, specifically those oriented northwest-southeast, are commonly associated with regional faulting.

Overburden is largely restricted to topograhic lows and, with the exception of recent bog or swamp deposits, consists predominantly of cohesionless silty to sandy till deposits and fluvial sands and gravels of glacial outwash origin. Till deposits also occur to a limited extent on the flanks of bedrock ridges.

2.4. Geohydrology and Geochemistry

The geochemical evolution of representative inactive pyrite tailings impoundments in the Elliot Lake uranium district has been summarized by Dubrovsky et al., (1985) and Feenstra, et al., (1981) and others. They showed that geochemical data obtained between 1979 and 1983 from networks of piezometer nests and cores from several inactive uranium tailings impoundments in the Elliot Lake district indicated that precipitation recharging the groundwater zone had been acidified at shallow depths in the tailings as a result of the oxidation of pyrite. This upper zone of low pH water, with high concentrations of sulfate, iron and heavy metals and higher concentrations of radionuclides, appeared to be expanding downwards. The original mill process water with neutral pH and low concentrations of heavy metals that was initially present in the tailings was gradually displaced by the downward migration of the low pH water from the active zone of pyrite oxidation. Further discussion of the details of the geochemistry of pyrite tailings is found in Dubrovsky, et al., (1985) and Feenstra, et al., (1981). In comparison to the detailed work at some other inactive uranium tailings sites in the Elliot Lake area, relatively little work had been carried out at the Lacnor tailings site prior to this study. The available information comprised the results of limited sampling programs of surficial tailings solids and of the tailings porewater.

A total of 12 surficial samples were collected in 1978, from the western end of the Lacnor tailings area, for pH determinations during studies for revegetation of the tailings (Rio Algom, unpublished information). These samples showed pH values between 2.4 and 3.1. Three samples were also analyzed to determine the grain size distribution of the tailings at the west end. These samples showed a variation of from 4.7 per cent to 27.3 per cent passing the 325 mesh in an area of coarse tailings in the area of the existing stream bed. It was inferred that these values showed that the Lacnor tailings were slightly coarser than the Nordic tailings.

Dubrovsky, et al., (1985) reported the results of analyses from a nest of piezometers in the Lacnor tailings area together with their more extensive work on the Nordic tailings area. Low pH waters were found to extend to a depth of approximately 6 m (with groundwater sampled from depths less than 4.6 m having pH values between 2 and 3.7) and high iron waters were found to occur through the entire thickness of tailings (approximately 8 m at the nest).

2.5 Meteorology, Air Quality and Radioactivity

2.5.1 Meteorology

A limited amount of long-term meteorological data is available for the Elliot Lake area and no data specific to the Lacnor site were found. Meteorological parameters of wind speed, wind direction, precipitation and temperature have been or continue to be measured at various locations in the Elliot Lake area.

Adjusted normals based on 19 years of data indicate that the mean daily temperature at Elliot Lake is 4.1°C and ranges from -11.7°C in January to 18.4°C in July. The daily minimum temperature ranges from -17.0°C in January to 18.4°C in July, while the daily maximum temperature ranges from -6.4°C in January to 24.2°C in July. Based on 13 years of data the extreme temperatures range from -42.8°C in February to 32.2°C during June and July.

Based on a 10 to 14 year period of record, the mean annual rainfall for Elliot Lake is 703.2 mm and the mean annual snowfall is 219.0 cm. The annual total precipitation is 926.3 mm with measureable precipitation occurring on 110 days.

Although wind data are available for the private aviation weather recording station at the Elliot Lake airport, the data have not been compiled to obtain any annual or seasonal trends.

2.5.2 Air Quality

Over the past 10 years several measurement programs and brief surveys have been carried out in the Elliot Lake area, however, none of them have gathered data specific to the Lacnor tailing area. The Nordic tailings area is the closest tailings area to Lacnor which has undergone air quality monitoring. Suspended particulate matter and dustfall sampling were carried out as part of these programs. Suspended particulate matter samples were analyzed for total particulate loading, total Uranium and Radium-226; as well as gross alpha and gross beta activity. The insoluble and soluble fractions of dustfall were determined along with gross alpha and gross beta levels for each fraction.

2.5.3 Radioactivity

Ambient radon and radon daughter concentrations, radon exhalation, and surface gamma radiation levels have been measured at a number of locations in the Elliot Lake area during the past 10 years. However, the only data collected directly relevant to Lacnor pertains to surface radiation measurements made during the 1977 field program for the environmental assessment of the proposed Elliot Lake uranium mines expansion. Gamma levels in the Lacnor tailings were found to be between 50 and 500 μR/h above background.

As with the air quality measurement program, the Nordic tailings area was the closest site to Lacnor, of numerous ambient radon, radon daughter, and radon exhalation measurements. The results of these measurement programs are presented in MacLaren (1978).

2.6 Surface Water

There are few historical data which have specifically measured surface water runoff and its chemical characteristics from the Lacnor site. A comprehensive data base and an analysis of chemical fluxes through the Serpent River watershed was developed by MacLaren (1978) as a part of the environmental assessment of mine expansion for Rio Algom and Denison. A comprehensive listing of data gathered in the Serpent River watershed is assembled in data publications such as Ontario Ministry of the Environment (1984). Data for the creek leaving the Lacnor tailings pond (called station L-03 by Rio Algom) are not included. The closest water quality station to the Lacnor tailings management area which is monitored on some kind of a regular basis and reported in public documents is the Nordic discharge (see N-17, Figure 2).

As a part of its monitoring program, Rio Algom has obtained samples from the outflow from the Lacnor pond for the period 1979 to 1984 on a monthly to bi-monthly basis. These data indicate the following range of values:

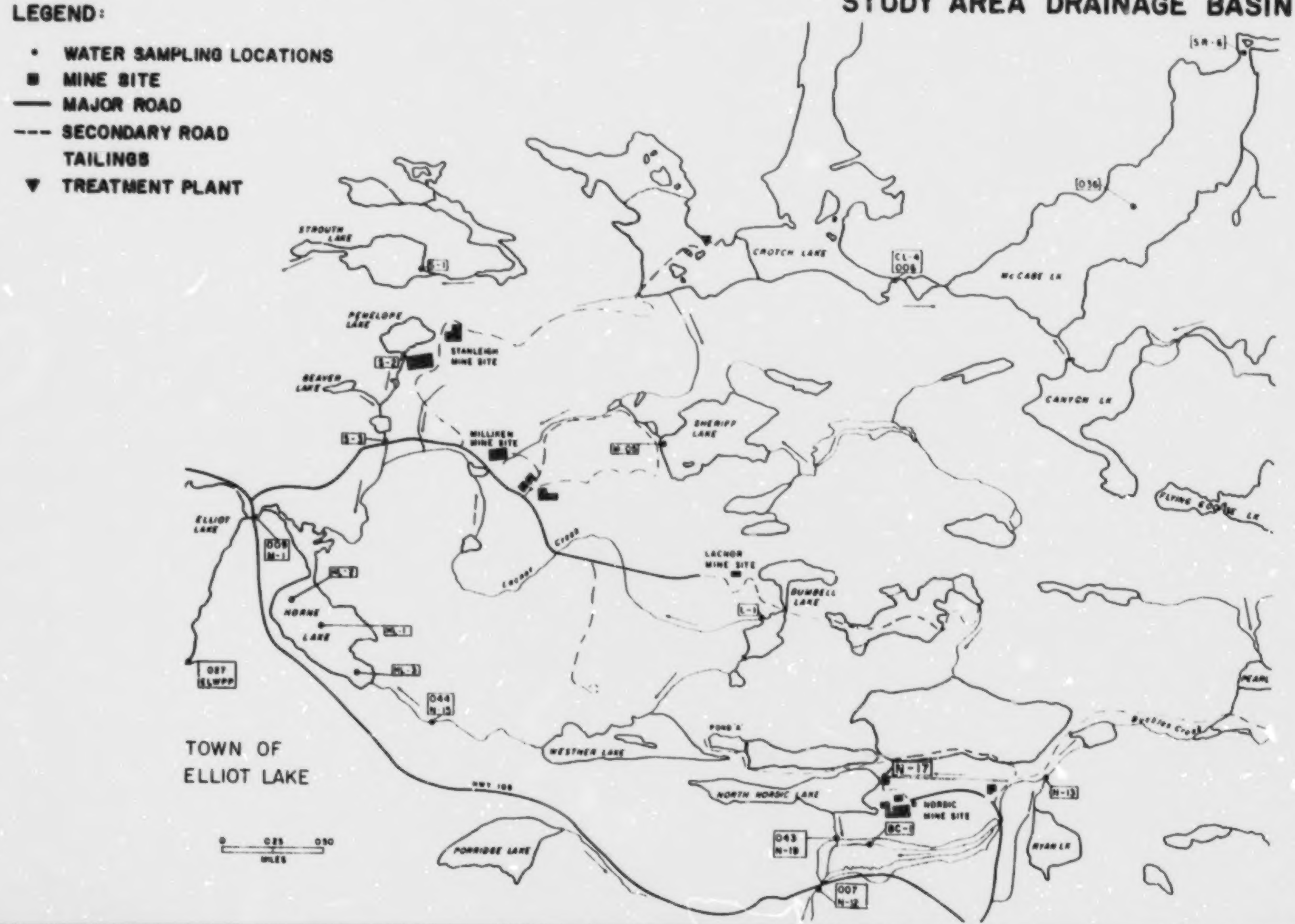
Parameter	Value
TDS (mg/L)	400 - 1500
Iron (mg/L)	10 - 110
Radium-226 (pCi/L)	5 - 60 (185-2220 mBq/L)
Acidity (mg/L, $CaCO_3$)	100 - 1500
pH	2.5 - 3.7

Flow rate measurements have also been made, permitting an estimate of the discharge load of contaminants to downstream.

A few samples have also been measured for trace metals. The values are of the following order: Pb (0.1 mg/L), Zn (0.1 mg/L), Ni (0.2 mg/L), Co (0.2 mg/L), Mn (2 mg/L), Cr (0.1 mg/L).

FIGURE 2

STUDY AREA DRAINAGE BASIN


LEGEND:
• WATER SAMPLING LOCATIONS
■ MINE SITE
— MAJOR ROAD
--- SECONDARY ROAD
TAILINGS
▼ TREATMENT PLANT
SR-6
036
CROTCH LAKE
CL-4
006
McCABE LK
CANYON LK
FLYING GOOSE LK
STROUTH LAKE
S-1
PENELOPE LAKE
S-2
STANLEIGH MINE SITE
BEAVER LAKE
S-3
MILLIKEN MINE SITE
M-05
SHERIFF LAKE
ELLIOT LAKE
008
M-1
H-2
HORNE LAKE
H-1
H-3
007
ELWPP
044
N-15
LACNOR MINE SITE
L-1
DUMBELL LAKE
POND 'A'
WESTNER LAKE
PEARL
Buckles Creek
N-17
NORTH NORDIC LAKE
NORDIC MINE SITE
N-13
043
N-19
BC-1
RYAN LK
007
N-12
PORRIDGE LAKE
HWY 108
TOWN OF ELLIOT LAKE
0 0.25 0.50
MILES

2.7 Biology

There are very few historical data from the study region which can be directly related to the Lacnor site. The Lacnor tailings site was only operated for about three years (1957 to 1960), at a time when monitoring was less sophisticated than at present. Because drainage from the Lacnor tailings flows directly into the much larger Nordic tailings, the overall environmental influences from the Lacnor tailings are largely masked by the effects of this larger operation.

2.7.1 Bacteria and Soils

No historical data were found on bacteria relevant to the Lacnor tailings. Several studies investigated concentrations of metals and radionuclides in tailings and vegetation growing on them in the Elliot Lake area. Other studies analyzed soils. In no cases could conclusive correlations between vegetation and substrate concentrations be reached. Radionuclides in no cases showed indications of bioconcentration from tailings or soils to vegetation.

2.7.2. Aquatic Biota

A large amount of regional data are available on aquatic biota. Data collected from the Elliot Lake sub-basin are affected by drainage from tailings at Lacnor and the approximately four times larger Nordic tailings. Due to Lacnor drainage being through the Nordic site, the direct relationship is probably small. It is probable that the presence of other larger tailings sites, some still operational, which drain into the Serpent River proper, would mask any effects of Lacnor on the aquatic biota of this basin.

Some data on benthic invertebrates indicate species diversity has been depressed in Nordic Lake which receives the main flow from the Nordic (and Lacnor) tailings (Shannon-Weiner Diversity Index 0.6 in 1977 (MacLaren, 1977)). Westner Lake which receives minor seepage flows from these tailings has also had its benthic diversity depressed (index 1.3), while Elliot Lake itself showed signs of moderately depressed benthic diversity (index 3.2). Clams were generally absent from lakes in the area, which has been attributed to their sensitivity to low pH. Zooplankton populations and species diversity were noted to decrease in waterways affected by drainage from uranium properties. MacLaren (1977) presented data indicating benthic populations and species diversity are depressed in waters receiving uranium tailings drainage.

Most fisheries data relevent to this study were extracted from studies carried out on the Serpent River. All regional data indicated this is an important pathway leading to human exposure (Corbett, pers. comm., 1985). MacLaren (1978) reviewed available data at that time and concluded there were no correlations between radionuclide levels in fish and the waters in which they were caught. MacLaren (1978) further reported that the Elliot Lake sub-basin was generally not affected by tailings effluents, except for Nordic and Westner Lakes which were virtually fishless.

No regional data of relevance to this study were found on amphibians or reptiles.

2.7.3 Vegetation

There are considerable data on vegetation for the Elliot Lake region. The area is within the Great Lakes-St. Lawrence Forest Region. The Espanola District is 76% productive forest (Corbett, pers. comm., 1985). Corbett provided further data indicating there are 91 farms in Spanish River Township totalling 11,557 ha. With a 180-day growing season, oats, barley and beef are the main produce. The Ontario Water Resources Commission (1972) indicated there was little production or use of home produce in the area, while MacLaren (1978) provided theoretical calculations estimating average annual ingestion rates of radionuclides from home produce as 1.3×10^4 pCi/a (480 Bq/a) of Ra-226 and 5.2×10^3 pCi/a (190 Bq/a) of Th-230. Further MacLaren (1978) data on vegetation sampling and analyses from the Elliot Lake area are presented in Appendix 4.

Considerable vegetation and vegetation-herbivore food chain research has been in progress in the Elliot Lake area, with several studies on the Lacnor and Nordic tailings (Ontario Environmental Assessment Board, 1979; and personal communications with Ontario Ministry of Environment, Laurentian University, University of Toronto, CANMET Laboratories, 1985). Although some of the data go back as far as 1977, researchers contacted indicated most of these data were pending publication and not available until then. Four publications were obtained.

Specific to vegetation on and in the vicinity of uranium tailings. At the time of writing, several publications on herbivores and transfer coefficients had recently been published or were in press. These are detailed in the following section of this report. McIlveen (1977) reported lead-210 results for soils and vegetation in the Elliot Lake area concluding that levels were elevated in the most common tree, white birch, in tailings areas. Kalin (1983, 1984) studied several tailings areas in the Elliot Lake region, including Lacnor and Nordic. Appendix 4 presents data from this study. In general, the conclusions were that neither radionuclides nor heavy metals showed significant trends in bioconcentration by vegetation. Davé et al. (1984) also indicated no correlation between radionuclide concentrations in vegetation and their tailings substrate. Levels of Ra-226, Pb-210 and total Pb were detectable in vegetation sampled, while levels of Th-232, Th-230, Th-228, total Th and total U were not. In their opinion the radium and lead concentrations in vegetation were not great enough to result in significant bioaccumulation in higher trophic levels.

2.7.4 Birds and Mammals

Historical data are available on the common species found in the vicinity of tailings areas in the Elliot Lake area (MacLaren, 1978), and hunting and trapping harvests of these (Ministry of Natural Resources, Blind River and Espanola Districts, pers. comm., 1985). Radionuclide levels in Elliot Lake area moose (Pb-210: 2.0 pCi/g (74 mBq/g); Ra-226: 0.09 pCi/g (3 mBq/g) and deer (Pb-210: 0.5 pCi/g (20 mBq/g); Ra-226: 0.15 pCi/g (6 mBq/g)) are provided by MacLaren (1978). A series of reports on small, mammalian herbivores, including studies at the Nordic and Lacnor tailings sites, have recently been published, are in press or are submitted for publication by researchers at Laurentian University and the CANMET, Elliot Lake Laboratories (Clulow, pers. comm., 1986). Two publications (Cluthier et al., 1985) and two in press (Cluthier et al., in press a and b) compare vole populations on Nordic Main with those on copper tailings and a control site. Ra-226 levels were only measureable in the substrate (7000 mBq/g), leachate (920 mBq/g) and vegetation (330 mBq/g) at Nordic. Voles living in this area had measureable Ra-226 in bone (1930 mBq/g), whole body (260 mBq/g) and gastrointestinal tract (110 mBq/g). Ra-226 levels were not measureable from the copper tailings or control site samples. Cluthier et al. (1986) calculated vole skeletal dose levels to be highest in spring on the Nordic tailings (4×10^{-4} Gray/day) but reported lifetime accumulations (2.5×10^{-2} Gray) to be below levels likely to cause cancers in the mice. They (in press a) also calculated vegetation - vole transfer coefficients for Ra-226 as follows (based on vegetation activities of 211 ± 22 mBq/g):

	Skeleton Concentration	Transfer Coefficient
Winter	6083 ± 673 mBq/animal	NA
Spring	7163 ± 1077 mBq/animal	NA
Summer	1506 ± 625 mBq/animal	$(4.6 \pm 2.9) \times 10^{-2}$
Fall	703 ± 59 mBq/animal	$(2.8 \pm 0.6) \times 10^{-2}$
Control	< 7.4 m Bq/animal	

A fourth paper, Cluthier et al. (in press b) reported activities of Ra-226 in snowshoe hare feces at Lacnor to be 203 ± 85 mBq/g. This was the highest of 3 tailings sites studied in the area and compares to a control value 3.7 mBq/g.

2.7.5 Human

A variety of historical data were obtained on such parameters as:

- concentrations of radionuclides in air and human inhalation rates
- concentration of radionuclides in town drinking water supplies
- average fish radionuclide concentrations and human consumption rates
- concentrations of radionuclides in home produce and average human consumption
- concentrations of radionuclides in game and average human consumption; this is reported as the most significant human exposure pathway (MacLaren, 1978)

2.7.6 General Terrestrial

Several groups including CANMET at Elliot Lake, the Biology Department of Laurentian University, Institute for Environmental Studies, University of Toronto, and the Sudbury office of the Ontario Ministry of the Environment (MOE) are currently conducting research on vegetation, mammals and bioaccumulation of radionuclides in the Elliot Lake region, including the Nordic/Lacnor area. As noted above, some of these studies (on Nordic Main) were published during the current study, while several papers are in press or to be submitted in 1986. The Atomic Energy Control Board (Maloney, pers. comm., 1986) will be publishing results of a study of moose and moose browse radiation levels in the near future. Data should be available from the above sources on metals and/or radionuclide concentrations in soils, bryophytes, vascular plants, and a variety of birds and mammalian herbivores.

3.0 GEOHYDROLOGY AND GEOCHEMISTRY

3.1 Geology of Basin

The Lacnor Tailings Basin is situated within a bedrock valley formerly occupied by swamp land. The tailings surface elevation is approximately 380 m above sea level. Ponded water currently covers the surface of the tailings in the east end of the basin.

The basin is surrounded by ridges of exposed bedrock that trend east-west. The ridge along the north side of the basin rises in south-facing, near vertical cliffs to elevations of 420 to 440 m. The ridge along the south side of the basin is less pronounced and rises to elevations of 400 to 410 m. It separates the Lacnor Basin from the Nordic Basin to the south. The ridge is cut by north-south and northwest-southeast trending valleys that form the drainage pathways from the basin.

The Lacnor Tailings Basin is largely underlain by quartzite metasedimentary rock of the Upper Mississagi formation. The steep ridges along the north side of the Lacnor Tailings Basin are intrusion diabase sills. A large diabase dyke, trending northwest-southeast occurs along the eastern side of the basin, accompanied by a smaller northerly trending, diabase dyke.

The Pecors Lake Fault, a major northwest-southeast trending structure passes diagonally through the central portion of the tailings basin and erosion of fractured rock associated with this feature has created the valley below the east dam. Diabase dyking is also associated with this fault. The large northwest-southeast trending diabase dyke that occurs along the eastern side of the basin is also considered to be related to the same structural episode as the Pecors Lake Fault. Both the faulting and parallel diabase dyking appear to post-date the intrusion of the massive diabase sills along the northern rim of the tailings basin.

Jointing within the rock, based on an examination of exposed surfaces, tends to comprise widely spaced, linear, smooth surfaced features. Three main joint sets were identified.

3.2. Tailings Solids and Underlying Overburden/Bedrock

The surface tailings samples were obtained during the site reconnaissance in November, 1984. Grain size distribution analyses confirmed that the surficial tailings varied from coarsest at the western end of the basin and along the northern half of the tailings area (sand with a trace of silt) to finest (a sandy silt) in the southeastern part of the basis.

Boreholes were put down at five locations across the tailings area (for locations of Boreholes, see Figure 3). The locations of the boreholes were selected to include areas of coarser sand tailings towards the western end of the basin and areas of finer tailings in the eastern and southeastern parts of the basin.

At each location, a series of boreholes were drilled to various depths within and beneath the tailings to obtain samples of the subsurface materials and for the installation of piezometers. Bedrock was cored in boreholes at two of the five locations, one in an area above an expected bedrock fault zone and the second above an area where unfaulted rock was anticipated. The number of boreholes in each nest was based on the material encountered in the initial borehole. Subsequent to the drilling and collection of soil and rock samples, piezometers were installed in each borehole. During the remainder of the field study groundwater samples were collected from selected piezometers and water levels were measured in all piezometers. Each borehole and piezometer was assigned an identification letter (a,b,c,d etc.).

Continuous sampling through the tailings was employed during the advance of the initial borehole at each location using hollow stem augers. A variety of sampling techniques were used including plastic liner sleeves in the continuous sampler, standard steel shells, tubes and a standard split spoon sampler. Standard penetration tests were conducted through the tailings at

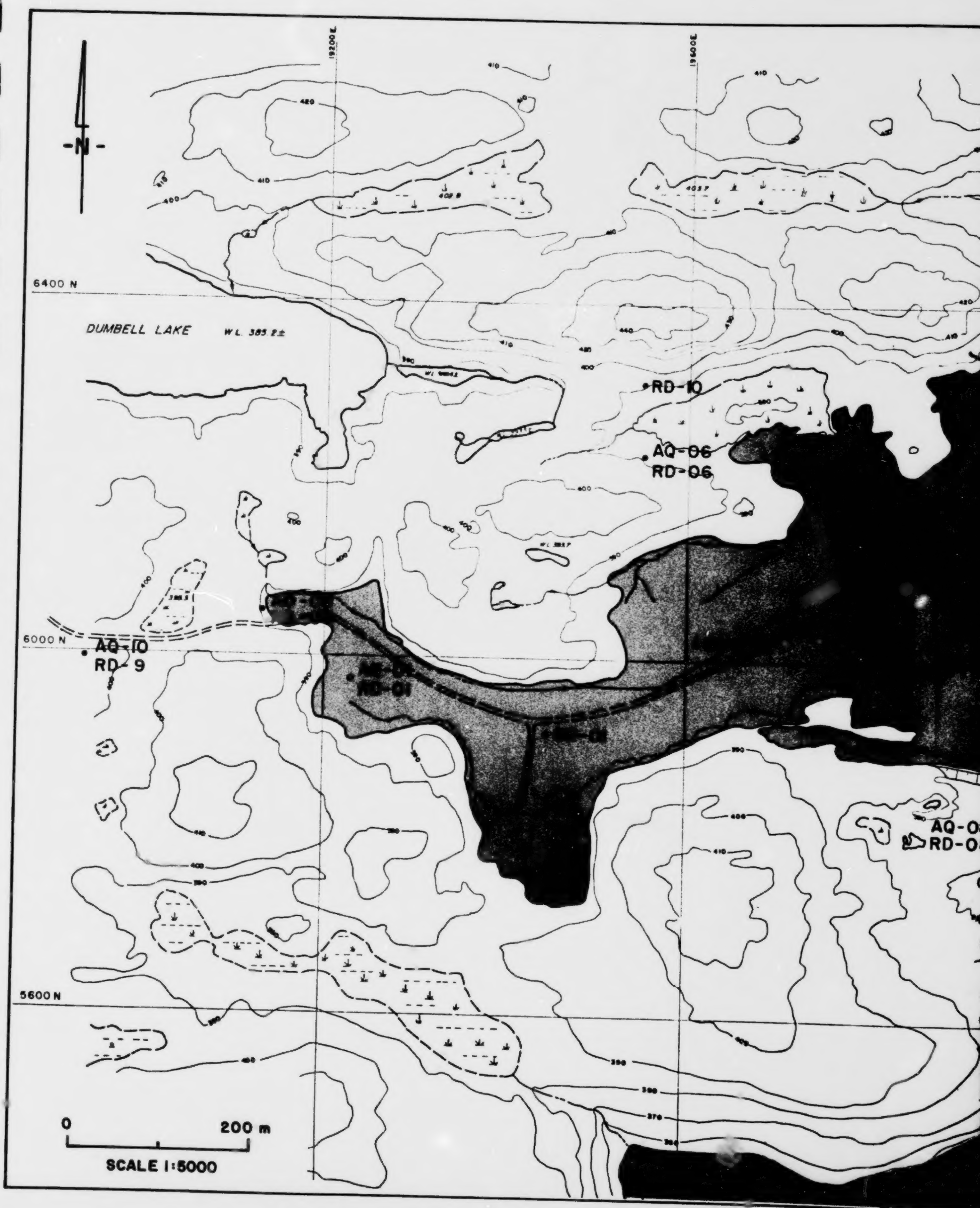
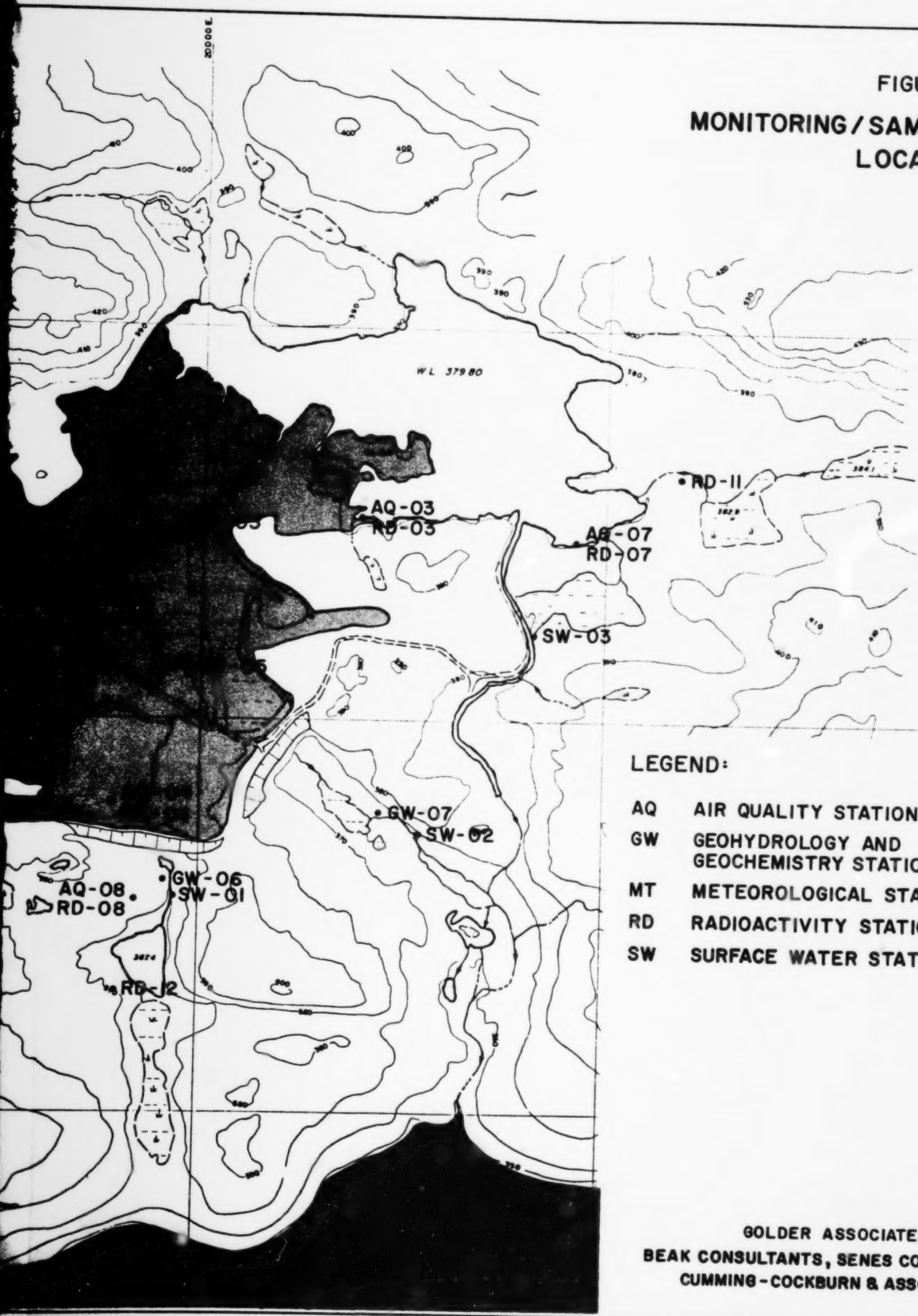

-N-
19200 E
19600 E
6400 N
6000 N
5600 N
DUMBELL LAKE
W.L. 385.2±
RD-10
AQ-06
RD-06
AQ-10
RD-9
RD-01
AQ-0
RD-0
410
420
400
390
440
430
380
370
360
0
200 m
SCALE 1:5000

FIGURE 3

MONITORING/SAMPLING LOCATIONS


20000 E
400
390
420
410
6400 N.
W.L. 379.80
RD-11
AQ-03
RD-03
AQ-07
RD-07
SW-03
6000 N
GW-07
SW-02
GW-06
SW-01
AQ-08
RD-08
RD-12

LEGEND:

AQ	AIR QUALITY STATION
GW	GEOHYDROLOGY AND GEOCHEMISTRY STATION
MT	METEOROLOGICAL STATION
RD	RADIOACTIVITY STATION
SW	SURFACE WATER STATION

GOLDER ASSOCIATES
BEAK CONSULTANTS, SENES CONSULTANTS
CUMMING-COCKBURN & ASSOCIATES

two sites (SO-01 and SO-04) and in the natural strata beneath the tailings at all locations. Boreholes at SO-01 and SO-05 were advanced up to 7.4 m into the underlying bedrock using N-sized diamond coring equipment. Details of each boring and piezometer installation are included in Appendix 1.

Between 7.9 m and 26.0 m of tailings were encountered at the five borehole locations across the tailings. The tailings were thickest at Borehole SO-05 and thinnest in the western end of the basin at the location of Borehole SO-01.

Two distinct types of tailings were encountered. The coarser type consisted of fine to medium sand with some silt (10 to 20 per cent silt) while the finer type generally consisted of silt sized tailings with a trace to some sand (1 to 20 per cent sand). Generally the two material types were distinct when observed in the field.

The finer type of tailings was found to be absent at SO-01 and 02, situated in the western portion of the basin. Boreholes at SO-03, 04 and 05 located in the eastern portion of the basin encountered interlayered fine and coarse tailings throughout most of their depths.

Pyrite was visible in most samples taken below the water table but was not visible in the oxidized zone generally within the upper 1 to 1.5 m of tailings.

Standard penetration tests carried out through the tailings at SO-01 and SO-04 indicated that the tailings ranged between loose and very loose in density.

Four types of sub-tailings overburden were encountered topsoil, till, peat, and glaciofluvial material such as sands, silts and gravels.

Topsoil was encountered at all but the SO-05 site ranging in thickness from less than a centimetre to a maximum of 0.15 m at SO-04.

A relatively thin layer of coarse silty sand till was encountered in all boreholes, ranging in thickness from 0.31 to 2.43 m. Attempts were carried out to core the till in the borehole at SO-02a with rotary diamond equipment; however, due to the non-cohesive nature of the material, only the coarser rock fragments were recovered.

A distinct layer of peat was encountered below the tailings of the SO-05 site and ranged in thickness between 0.3 to 1.68 m. A distinct peat layer was not encountered at the other borehole locations across the tailings.

Glaciofluvial materials ranging from silts to coarse sands and gravels were encountered below the peat in several boreholes at the SO-05 site. The total thickness of the glaciofluvial materials was approximately 7 m and included sand and gravel silt.

Both boreholes advanced into bedrock encountered quartzite, although that at SO-01 was relatively intact and that at SO-05 was extensively jointed.

Eighteen tailings and subtailings solids samples were subjected to geotechnical tests. Gradation tests confirmed that the tailings varied from sand with a trace of silt at the western end of the basin (sites SO-01 and SO-02) to predominantly silt sized material in the eastern and southeastern portion of the basin (Boreholes SO-03, 04 and 05). However, coarser sand tailings were also encountered within the tailings solids samples recovered from the three easterly boreholes.

Laboratory permeability tests on two undisturbed Shelby tube samples of sandy tailings from borehole at SO-01 gave vertical coefficients of hydraulic conductivity of 2×10^{-3} and 9×10^{-4} cm/s, while those on two samples of silt tailings from Borehole SO-03 gave vertical permeabilities of 1×10^{-5} cm/s. These results are consistent with other measurements in the Elliot Lake area, although relatively high.

The chemical composition of the tailings and sub-tailings solids was determined on selected samples collected during the borehold drilling program. The chemical testing program included analyses for major cations, metals and general parameters such as cation exchange capacity and various forms of carbon and sulfur on 25 samples. Radiological parameters were determined for 14 samples. The major cations, anions and general water quality parameters were determined on three types of extractions from each of the samples: water leach, dilute acid leach and strong acid digestion.

No distinct trends in variability of the composition of the tailings with depth were indicated by the data. Much of the tailings solids material consisted of relatively insoluble aluminosilicate minerals; concentrations of silicon, aluminum, sodium and potassium were high in the total acid digestions of the samples. Soluble sulfur, which likely was present in the tailings primarily as gypsum (calcium sulfate), occurred at concentrations as high as 5 per cent. Measured concentrations of reduced sulfur, which was assumed to exist as pyrite, were less than 3 per cent. Sulfide minerals were observed in the tailing solids samples collected from the Lacnor basin but the reported concentrations of reduced sulfur were relatively low in comparison with previously reported values for other tailings basins in the Elliot Lake area. Carbonate concentrations in the tailings solids were low, typically less than 0.1 per cent.

Uranium concentrations in the tailings solids ranged from 10 to 80 ppm. Radium-226 and Thorium-230 concentrations ranged from 0.6 to approximately 12.5 Bq/g.

3.3 Off-Tailings Rock

A total of nine separate boreholes were drilled at two sites south of the basin in the valleys in the vicinity of the surface water monitoring locations SW-01 and SW-02. Based on the geological mapping of the basin and previous experience in the Elliot Lake area, these valleys were considered to contain the major potential fault or fracture zones, and hence the major groundwater seepage pathways exiting from the tailings area.

Three boreholes were put down at SO-06 and six were advanced at SO-07. At angles between 55 and 68 degrees. The boreholes were oriented to intersect what were considered to be the major geological features within each valley at varying depths. The details of each boring are summarized in Appendix 1.

At SO-06, there was a change in colour of the cuttings at depths between 29.9 to 30.3 m in Borehole SO-06a and at 15.2 m in Borehole SO-06b. The location of these colour changes coincides closely with an extrapolation to depth of the near vertical cliff adjacent to surface water monitoring location SW-01.

At SO-07, the frequent change in rock type, water bearing seams encountered in the boreholes and the surface bedrock exposures indicate that northwest-southwest trending near vertical diabase dykes and shear zones strike through the valley.

3.4. Groundwater/Porewater

Piezometers (monitoring wells) constructed of PVC were installed in the tailings and underlying subsoils in individual holes. They were of similar construction to those used in previous porewater investigations of uranium tailings areas in the Elliot Lake area. Piezometers of generally similar construction but different lengths of intake screens were installed in the two cored bedrock holes beneath the tailings and in the nine bedrock holes in the stream valleys.

Eight piezometers from a previous investigation of subsurface conditions in the Lacnor tailings were incorporated into the monitoring network for this study at GW-02. For each borehole location, the prefixes WL and GW were used to refer to water levels and porewater samples respectively from particular piezometers. For example, WL-01a and GW-01a referred to water levels and porewater samples from the piezometer in Borehole SO-01a.

Water level measurements were made at approximately monthly intervals in all monitoring wells. Water levels in the monitoring wells installed in and below the tailings generally decreased by 0.5 to 1.0 m between April and July, generally reaching their lowest measured levels in July. The highest water levels were generally recorded in March or April. There was a tendency for low but slightly downward hydraulic gradients within and below the tailings, although those were affected at SW-02 by the presence of the peat beneath the tailings which acted to restrict downward flow.

Rising head hydraulic conductivity tests were carried out in various piezometers subsequent to their installation. In addition, falling head tests employing mechanical packers were conducted in the bedrock during the drilling of a borehole at SU-05.

The _in situ_ hydraulic conductivity tests for the various tailings, sub-tailings and off-tailings geological materials are summarized below:

Fine Tailings	2×10^{-6} to 2×10^{-5} cm/s
Coarse Tailings	1×10^{-5} to 5×10^{-4} cm/s
Sand and Gravel below Tailings	8×10^{-4} to 1×10^{-3} cm/s
Bedrock	3×10^{-7} to 3×10^{-3} cm/s

The _in situ_ hydraulic conductivity tests in the tailings gave hydraulic conductivities which were generally lower than those determined from constant head laboratory permeameter tests on samples of coarse and fine tailings (approximately 10^{-3} and 10^{-5} cm/s, respectively).

The chemical composition of the tailings porewater and the sub-tailings and off-tailings groundwater was monitored in selected piezometers in June and August 1985. The monitoring programs routinely included the measurement of pH, electrical conductance, temperature, dissolved oxygen, ferrous iron and acidity in the field at the time of sample collection and analyses for major anions, major cations, metals and radiological parameters. Sampling of selected piezometers was conducted at the seven tailings and off-tailings monitoring stations. The variability of the chemical composition of the porewater as a function of depth was monitored in detail at two monitoring stations in the tailings basin; one station was in area where the sediments were predominantly coarse sand-sized and the other station was in an area of interlayered fine and coarse tailings sediments.

The chemical characteristics of the porewater existing in the Lacnor tailings basin in 1985 had been influenced by the initial composition of the process water and solids originally discharged to the basin and the low pH recharge water that had developed as a consequence of pyrite oxidation at shallow depths within the tailings since their deposition. The porewater was characterized by elevated electrical conductance values and high concentrations of iron and sulfate. The porewater was generally acidic at shallow depths and moderately acidic to neutral at depths of more than several metres within the tailings.

The pH increased and electrical conductance decreased with depth in the porewater at monitoring stations GW-01 and GW-02 in the coarse tailings in the western sections of the basin. In the interlayered fine and coarse tailings at monitoring stations GW-03, GW-04 and GW-05, the profiles of pH and electrical conductance in the porewater were not depth dependent. The observed trends in this area of the tailings may have been influenced by the unusual occurrence of ponded surface water during the spring and early summer of 1985.

The concentrations of the primary dissolved constituents in the porewater such as sulfate, iron and the major ions and the concentrations of metals within the porewater were variable across the tailings, but in many cases the peak concentrations were associated with low pH.

With the exception of uranium, which exhibited a trend of increased concentrations with depth, the concentrations of radiological parameters in the porewater typically did not vary with depth in the tailings. In the area of coarse tailings, concentrations of Radium-226 and Thorium-230 in the porewater increased and decreased, respectively with depth, but the same trends for these and other radiological parameters were not apparent in the areas with interlayered fine and coarse tailings.

The monitoring program indicated that the chemistry of the groundwater in the sub-tailings overburden and, to a lesser extent, the sub-tailings bedrock, had been influenced by the tailings porewater. However, impacts of the tailings on the groundwater chemistry in the bedrock piezometers at off-tailings monitoring stations were generally very low.

4.0 METEOROLOGY, AIR QUALITY, AND RADIOACTIVTY

4.1 Meteorology

4.1.1 Station Locations and Parameters Measured

During the Lacnor field study, meteorological conditions were monitored at three locations using various pieces of meteorological devices.

Station MT-01, located on the Lacnor tailings area, was the main meteorological station. At this location the parameters of wind speed and direction (at a height of 10 m), temperature, solar radiation, and evaporation were monitored. At station MT-02, located to the south of MT-01 on the Nordic tailings area, wind speed and direction were measured (at a height of 10 m). The third station MT-03 was located on the roof of the CAIRS office at 7 Timmins Road in the Town of Elliot Lake. At this station temperature, relative humidity, barometric pressure and precipitation were monitored.

4.1.2 Wind

The average monthly windspeed at MT-01 was 8.7 km/h and ranged from 7.0 km/h in August to 11.0 km/h in March. Over 30% and 31% of the winds measured at this location originated from the northern and western sectors respectively. An average of 49 hours of calm conditions per month was recorded at this station. The average monthly windspeed at MT-02 was higher than MT-01 at 10.9 km/h with a greater range in averages from 7.6 km/h in December to 16.0 km/h in March. Wind direction was more evenly distributed about the four quadrants with 28% and 26% of the winds recorded originating from the west, and both north and east quadrants respectively.

4.1.3 Temperature

The mean daily temperature for the ten-month monitoring period of January to October 1985 at MT-01 was 6.3°C and ranged from -12°C in January to 20°C in

July. The temperature extremes at this station were -27°C to greater than 29°C. The mean daily temperature for the corresponding period at MT-03 was 5.6°C and ranged from -12°C in January to 17°C in July. The temperature extremes at this station were less than -20°C to 28°C.

4.1.4 Precipitation

The total amount of precipitation measured at MT-01 for the observation period of 19 December 1984 to October 1985 was 695 mm. Monthly total amounts ranged from 38 mm in September to 137 mm in August. At MT-03 the total for the same period was 672 mm, with monthly totals ranging from 33 mm in January to 103 mm in August.

4.1.5 Solar Radiation

The monthly total solar radiation measured at MT-01 ranged from a low of 2,944 Langleys (cal/cm^2) in January to a high of 15,338 Langleys in June. On a daily basis, the mean amount of solar radiation ranged from 95 Langleys in January to 518 Langleys in June.

4.1.6 Evaporation (Class A Pan)

The class A evaporation pan assembly was in operation from 01 May to 31 October 1985. The Class A pan is a cylindrical container 122 cm in diameter and 25 cm deep. The mean monthly evaporation was 106 mm and ranged from 34 mm in October to 178 mm in July.

4.1.7 Relative Humidity and Barometric Pressure

These parameters were measured at MT-03 using a meteorograph equipped with a human hair bundle to sense changes in levels of relative humidity and a 14-cell 51 mm diameter aneroid pressure sensor. Details on the readings obtained are provided in Appendix 2.

4.1.8 Snow Depth and Water Equivalent

The depth of snow and water equivalent were measured during two separate winter-period compaigns. For the mid-winter program in March the average snow depth over the tailings was 54.8 cm and ranged from 35.6 to 68.6 cm. The average ratio of snow volume to water volume was 3.6:1 and ranged from 3.0 to 5.3:1. At the time of the pre-freshet program in April the depth of snow pack had reduced some 31 cm. The average snow depth was 24 cm and ranged from 11.2 to 32.0 cm. The average ratio of snow volume to water volume was 1.9:1.

4.2 Air Quality

4.2.1 Monitoring Program

Air quality was monitored at eight locations for dustfall and at two locations for suspended particulate matter (SPM). Dustfall was measured at stations AQ-01 to AQ-08 while SPM was measured at AQ-09 and AQ-10.

4.2.2 Dustfall

Monthly dustfall samples were analyzed to determine the organic/mineral and soluble/insoluble fractions. Three-month composites of the inorganic fractions for each site were prepared and analyzed for various radionuclides. Samples from the four sites on the edge of the tailings were analyzed for Radium, Thorium-228 to 232, Lead-210 and Uranium. The four off-tailings samples were analyzed for only Radium, Thorium-230 and Uranium.

Total dustfall levels measured during the January to October period ranged from 0.12 to 5.35 g/m^2/30 days with an overall average for the 70 samples of 1.4 g/m^2/30 days. Organic contents ranged from 39 to 95% with generally higher percentages for the off-tailings sites. With respect to radionuclide analyses Lead-210 activity per gram was the highest of the five parameters for the four on-tailings sites and ranged from 0.05 to 1.10 Bq/g. For the four off-tailings sites Radium-226 activity per gram was equal to or higher than

Thorium-230, and ranged from 0.004 to 0.169 Bq/g. Uranium levels at the eight sites ranged from 0.07 to 1.11 ug/g, with an overall average for the 24 composites of 0.32 ug/g.

4.2.3 Suspended Particulate Matter

Suspended particulate matter (SPM) samples were collected at two sites as part of air quality monitoring. Site AQ-09 was located on the tailings in close proximity to the MT-01 station. Site AQ-10 was located off-tailings some 250 m west of the most westerly arm of the Lacnor tailings area. Two particle size ranges were collected at each site, by operating one high volume sampler in the standard sampling configuration (particle size < 50 micron) and the other with a selective size inlet head (particle size < 10 micron) to sample the respirable fraction of SPM. The samplers were operated for one full day (24 hours) approximately every six days, based on the schedule of the National Air Pollution Surveillance (NAPS) network. Because the samplers were powered by portable generators some deviation from the NAPS schedule did occur.

For the on-tailings site (AQ-09) the total SPM levels ranged from 3.4 to 51.6 ug/m^3, while the respirable SPM level ranged from 0.4 ug/m^3 to 27.1 ug/m^3. The mean ratio of respirable SPM to total SPM was 0.61 and ranged from 0.06 to 0.87.

For the off-tailings site (AQ-10) the total SPM levels ranged from 2.1 to 48.8 ug/m^3, while the respirable SPM level ranged from 0.6 to 26.3 ug/m^3. The mean ratio of respirable SPM to total SPM was also 0.61 and ranged from 0.22 to 0.96.

Monthly composites of each sampler's filters were prepared and analyzed for Uranium and Radium-226, Thorium-228, -230 and -232 and Lead-210. Uranium levels ranged from 2.6 to 70 ug/g and 11 to 195 ug/g about a geometric mean of 21 and 61 ug/g for off-tailings and on-tailings samples respectively. Of the 5 radionuclides Lead-210 activity per gram was the highest and ranged from < 0.1 to 53 Bq/g and 2 to 53 Bq/g about a geometric mean of 9 and 19 Bq/g for off-tailings and on-tailings samples respectively.

4.3 Radioactivity

4.3.1 Program Description

The measurements of radioactivity described in this section pertain to ambient radon, radon exhalation and gamma radiation.

4.3.2 Radon Monitoring

Ambient radon levels were measured at twelve locations (RD-01 to RD-12) in the vicinity of the tailings. Sites RD-01 to RD-04 were located at the edge of the tailings; RD-05 to RD-08 were located less than 100 m off the tailings; and RD-09 to RD-12 were located some distance off the tailings (> 100 m). The radon levels at RD-01 to RD-04 ranged from less than 0.002 to 0.039 Bq/L; at RD-05 to RD-08 ranged from 0.003 to 0.040 Bq/L; and at RD-09 to RD-12 ranged from 0.005 to 0.030 Bq/L.

4.3.3 Radon Exhalation

Radon exhalation rates from the surface of the tailings were determined for various tailings conditions over discrete time intervals at twenty four locations. The exhalation rates (fourty-four in total) ranged from a low of 0.0089 Bq/m^2/s in March on a dry, hard sandy tailings surface to 6.67 Bq/m^2/s in June on a damp non-vegetated surface. The tailings conditions sampled include: frozen, dry, damp, saturated, water- covered, vegetated and non-vegetated.

4.3.4 Surface Gamma

A comprehensive surface gamma radiation survey of the tailings area was carried out on a 30 m X 30 m grid applied over the site. The contact gamma levels on the tailings range from a low of 30 uR/h to a high of 1100 uR/h.

The higher gamma levels (> 500 uR/h) were found on the eastern third of the site with several areas supporting gamma levels in excess of 1000 uR/h.

5.0 SURFACE WATER

5.1 Design of Measurement Program

The surface water measurement program was designed to provide accurate data for future input to a suitable hydrologic model for the purpose of assessing the net amount and quality of water exiting the Lacnor basin as surface runoff.

5.2 Hydrologic Studies

At the three surface water monitoring locations, shown on Figure 3 as SW-01, SW-02 and SW-03, concrete weirs with steel V-notch centre plates were installed. The weirs installed on West and East Creeks (SW-01 and SW-02 respectively) were located to monitor seepage from the tailings, while the weir at SW-03 was installed on Lacnor Creek to monitor the outflow from Lacnor Pond. At all three locations water levels were monitored on a continuous basis using Leupold-Stevens Model A-71 float-operated water level recorders.

Flow monitoring was initiated in mid-February 1985, however, problems with water freezing in the stilling wells prevented accurate measurements for the period prior to mid-March 1985. Continuous discharge monitoring was achieved over the period, March 23, 1985 through November 3, 1985.

As a result of high flow and the collapse of a decant tower downstream at the Nordic tailings area during the spring freshet, Rio Algom constructed an earthfill dam at the outlet of the Lacnor Pond just upstream of station SW-03. The dam was intended to attenuate the flow from the Lacnor tailings area and reduce the flooding being experienced downstream in the Nordic basin.

As a result of this dam the water level of Lacnor Pond was increased by more than 60 cm. This caused water to back up and overflow onto the Lacnor tailings. The net effect of the earthfill dam was to reduce the recorded flows at SW-03 and increase the flows being recorded at SW-02. Because the earthfill dam was in-place from April 24 to June 17, 1985, discharge records for this period should be interpreted with caution as a result of the man-made attenuation to the natural drainage characteristics of the area.

Table 5.1 presents a summary of the results obtained at the three stations.

The measurements made at stations SW-01 and SW-02 indicate that seepage rates are relatively constant on a seasonal basis. Mean monthly flows ranged from 0.18 L/s in July to 0.45 L/s in May at SW-01, with a maximum daily flow of 2.66 L/s recorded on April 23. At SW-02 the mean monthly flows ranged from 1.2 L/s in September to 12.3 L/s in May. The maximum daily flow at this location occurred on April 27 and was recorded at 18.11 L/s. During the period in which the earthfill dam was in-place the recorded flows at SW-02 were from 3.5 to 9 times greater than those measured during the post-dam period.

The flows recorded at SW-03 were much more variable than at the other two locations. The mean monthly flows ranged from 0.54 L/s in September to 123.6 L/s in April. The maximum daily flow recorded was 1026 L/s on June 17, 1985. Prior to the installation of the earthfill dam, flows were measured at 530 L/s; however, following installation of the dam the flows dropped to less than 10 L/s and during the month of May averaged 3.9 L/s.

5.3 Surface Water Chemistry

Water samples were obtained from the three surface water streams at the water-level gauging stations SW-01 to SW-03 shown on Figure 3. The samples were returned to a field laboratory within 2 hours, split and preserved for subsequent shipment to the main laboratory. Splits of the samples were analyzed at the field lab for time-sensitive parameters (DO, pH, acidity, Fe^{2+}, Eh, conductivity). These operations and sample shipments were completed within 6 hours of taking the first sample.

Table 5.1

SUMMARY OF RECORDED FLOWS AT THREE SURFACE WATER STATIONS - 1985(1)

Site	Month	Number of Data-Days	Mean Daily Flow (L/s)	Minimum Daily Flow (L/s)	Maximum Daily Flow (L/s)
SW-01	MAR	2	---	0.87	0.97
	APR	25	1.24	0.70	2.66
	MAY	31	0.45	0.25	0.91
	JUN	30	0.32	0.15	0.57
	JUL	31	0.18	0.12	0.54
	AUG	31	0.20	0.11	0.61
	SEP	30	0.24	0.13	0.46
	OCT	31	0.28	0.16	0.40
	NOV	4	---	0.30	0.98
SW-02	MAR	20	1.90	1.55	3.06
	APR	30	7.49	1.73	18.11
	MAY	31	12.30	7.05	17.5
	JUN	30	4.84	1.45	10.7
	JUL	31	1.40	1.03	4.08
	AUG	31	1.31	0.94	3.07
	SEP	30	1.20	0.94	2.22
	OCT	31	1.65	0.99	4.22
	NOV	4	---	1.38	5.85
SW-03	MAR	6	---	42.8	46.5
	APR	30	123.6	7.13	539
	MAY	31	3.92	1.51	6.75
	JUN	30	63.8	0.28	1026
	JUL	31	0.42	0.16	0.61
	AUG	30	1.18	0.35	6.37
	SEP	30	0.54	0.16	2.5
	OCT	31	7.99	0.42	2.17
	NOV	3	---	2.56	29.0

Note

1) See text and Appendix 3 for discussion of estimated flows, regulated flows, ice conditions and earthfill dam upstream of SW-03

Although the field period covered November 1984 to October 1985 (incorporating an annual hydrological period), the first samples were taken in January 1985 due to contract start-up and logistical considerations. Table 5.2 presents a summary of the major sampling features for the surface water chemistry component. Sampling continued on a monthly basis until early March when a regular weekly period commenced. This schedule was changed twice:

(i) on April 24 after the start of spring melt, and
(ii) in mid-July when the sampling interval was extended to a ten to fourteen day interval.

As well, one set of surface water samples was taken at eight locations around the surface of the tailings area in late April before the surface snow had completely melted.

The hydrology of the tailings has been described above. The main impact upon surface water chemistry is 3-fold.

(i) The seepage streams (SW-01, SW-02) flowed at approximately a constant rate throughout the year with only a minor increase during spring melt. An exception is an elevated flow rate at SW-02 for several days after April 24 due to overflow from the surface, short-circuiting through an abandoned channel. This resulted in some particulate tailings flowing with the stream. Flow at SW-02 is larger than premelt conditions for approximately two months. However, the presence of particulate material was only observed for several days after April 24.

(ii) The water flow of SW-03 is from a pond. This pond acts as a settling basin in which Fe^{2+} can be oxidized to Fe^{3+} and settle as iron hydroxide. The extent of coprecipitation and adsorption for removing other cations is unclear. The stream has substantially different concentrations of cations than the other two streams.

Table 5.2

MAJOR SAMPLING FEATURES OF SURFACE WATER CHEMISTRY

Date	Feature
January 23	First Sample Taken
February 18-22	Second Sample Taken
March 12	Regular Sampling Commenced
April 22	Spring Runoff Sampling Commenced
April 24	Rio Algom Blocked Outflow from SW-03
May 9	Sampling Interval Changed Back to Weekly
June 17	Rio Algom Removes Blockage to SW-03
July 11	Sampling Interval Changed to ten to fourteen days
October 31	Sampling Completed

(iii) SW-03 was temporarily blocked by Rio Algom for a period from April 24 through to June 17 to prevent the pond from discharging. This action was taken to aid hydraulic control of downstream ponds which were flooding. Water continued to flow through the barrier, but was minimal. Water which seeped through the barrier had substantially lower concentrations of cations because of adsorption processes by the till barrier. Samples for chemical analyses were initially taken downstream of the barrier and subsequently just upstream of the barrier. These upstream samples thus represent the pond's contents and the material exported from the pond.

Description of Results

Analysis of the chemical results (presented on Table 5.3; and Appendix Tables 3.5 to 3.10) shows that the dominant cations in the charge balance are iron and calcium. Aluminum, magnesium, and hydrogen ion make lesser but significant contributions to the cation charge balance. The anionic charge balance is explained almost solely by sulphate ion. Due to the low pH (3 - 4), bicarbonate ion is negligible. The charge balance for cations and anions are generally of the order of 10%.

Acidity is a measure of the total base neutralizing capacity of the samples. It is a useful tool for summarizing the combined effects of Fe^{2+}, Fe^{3+}, and H^+ in the water samples. The acidity range of the two seepage streams is larger than for the pond outlet; this is reflected by the lower iron concentrations in the pond outlet. Furthermore, the pH of the 2 seepage streams appears to be different from the pH of the pond outlet (see Appendix 3), although this is not reflected by the range given in Table 5.3.

Table 5.3

RANGE OF PARAMETERS MEASURED IN FIELD STUDY

(Units: mg/L unless noted)

	SW-01	SW-02	SW-03
Conductivity (uS/cm)	10800-30500	12200-43000	1000-14900
Acidity(as $CaCO_3$)	365-2700	476-3510	40-660
pH(units)	2.95-3.85	2.9-3.5	2.8-5.4
DO	4.8-6.6	4.5-8.8	4.2-9.8
Eh(mV)	325-420	340-400	410-585
Temperature(°C)	0-17	0-22	0-18
TDS	1810-3900	1180-7200	40-560
TIC	1-30	< 0.5-3.0	1-5.5
TOC	3-9	4-10	< 0.5-4.0
TKN	0.69-100	1.30-17.2	0.24-6.9
TP(ug/L)	10-250	7-250	3-200
Ag	< 0.005-0.01	< 0.005-0.02	< 0.005-0.01
Al	13.3-38.6	9.95-18.7	0.41-13.2
As(ug/L)	< 1-9	< 1-4	< 1-10
B	< 0.004-0.92	< 0.004-2.03	< 0.004-0.472
Ba	< 0.005-0.012	< 0.005-0.08	0.006-0.030
Be	0.0010-0.0028	< 0.0005-0.0023	< 0.0005-< 0.01
Ca	103-401	102-407	5.33-107
Cd	< 0.01-0.26	< 0.01-0.48	< 0.01-0.065
Co	0.13-0.34	0.07-0.44	< 0.05-0.20
Cr	< 0.01-0.32	< 0.01-0.57	< 0.01-0.06
Cu	0.052-0.222	0.04-0.091	<0.008-0.77
Fe_T	73.7-800	153-1690	12.6-183
Fe^{2+}	56-780	145-1510	4-185
K	2-15.9	1-46	< 1-5.1
Mg	12-58.2	23.5-162	2.28-28
Mn	0.49-3.6	1.63-16.9	0.14-1.97
Mo	0.04-1.1	0.1-2.7	0.02-0.2

Table 5.3 continued

	SW-01	SW-02	SW-03
Na	1-10.4	1-42	< 1-6.5
Ni	0.12-0.30	< 0.05-0.32	< 0.05-0.15
Pb	< 0.05-0.42	< 0.05-0.56	< 0.05-0.19
Se (ug/L)	< 0.5-< 4	< 1-< 4	< 1-< 4
Si	13.5-27.7	2.02-21.7	1.8-17
Sr	0.11-0.42	0.08-0.82	0.014-0.79
Th	0.13-0.91	0.14-0.47	< 0.05-0.29
Ti	0.007-0.22	< 0.005-0.29	< 0.005-0.30
V	< 0.005-0.067	< 0.005-0.128	< 0.005-0.029
Zn	0.10-0.32	< 0.05-0.25	< 0.05-1.29
Zr	0.06-0.16	< 0.05-0.22	< 0.05-0.07
F^-	0.28-3.22	0.22-4.08	0.02-1.02
Cl^-	1.26-5.6	3.66-26	0.12-6.7
NO_2^-	< 0.02-10	< 0.02-20	< 0.02-5
PO_4^{3-}	< 0.1-<100	< 0.1-<100	< 0.1-< 100
Br^-	< 0.1-< 5	< 0.1-< 5	< 0.05-< 0.1
NO_3^-	< 1-1	< 0.5-< 30	0.05-14
SO_4^{2-}	571-2500	310-4800	21.6-800
U (ppm)	0.16-0.50	0.067-0.193	0.010-0.200
Th-230 (Bq/L)	3.41-25	1.7-8.0	0.55-14.1
Ra-226 (Bq/L)	0.41-1.8	0.18-1.2	0.35-1.0
Pb-210 (Bq/L)	0.14-5.4	0.11-2.7	0.11-3.1
Po-210 (Bq/L)	0.22-3.1	< 0.01-0.95	0.23-0.93
Th-232 (Bq/L)	0.12-4.9	0.18-1.1	< .05-1.78
Ra-228 (Bq/L)	< 0.4-<4	< 0.4-< 4	< 0.4-3.3
Th-228 (Bq/L)	0.09-2.0	0.012-1.4	0.11-1.29

The pH in the streams is influenced by the extent to which Fe^{2+} has been oxidized and the concentration of total iron. In the two seepage streams, Fe^{2+} constitutes in excess of 90% of Fe_T whereas it constitutes a varying percentage of Fe_T in the pond outlet. The effect of Fe^{2+} upon pH can be explained by the reaction:

$$4\ Fe^{2+} + O_2 + 10\ H_2O = 4Fe(OH)_3\ (s) + 8\ H^+$$

Fe^{2+} which seeps to the pond would cause a production of H^+ and hence a decrease in pH if it were oxidized. The exact pH change depends upon hydrolysis of other ions, and their complexation with sulphate.

The sulphate and calcium concentration in the pond outlet are substantially less than in the seepage streams as a result of dilution with runoff from the surrounding watershed. The aluminum and potassium concentrations presumed to result from acid attack upon aluminosilicates (e.g. sericite) in the tailings are similar in all three streams.

Most other parameters have concentrations in the sub-mg/L range (e.g. Ag, B, Ba, Be, Cd, Co, Cr, Cu, Mo, Ni, Pb, Sr, Th, Ti, V, Zn, Zr, F^-, NO_2^-, NO_3^-, TP, Br^-) with several being at or below the detection limit (Ag, Ni, Pb, V, NO_2^-, NO_3^-, Br^-). Several anions have a relatively high detection limit (NO_2^-, NO_3^-, PO_4^{3-}) on the ion chromatographic instrument due to sulphate interferences. The parameters As and Se, were generally at or near detection limit (1 ug/L).

Radionuclide parameters generally show an order of magnitude variation. A wider range was also observed in interlaboratory comparison studies for radionuclides than for normal cations. This is thought to be due to sample preparation procedures (concentration precipitation-purification of the radiocations from liquid samples). It is also possible that sample preservation treatment before sample transport to the laboratory was not completely effective for all samples.

The activity of U is less than that of Th-230 reflecting mill extraction of U. The activity of Th-230 is approximately an order of magnitude larger than that of its daughters Ra-226, Pb-210 and Po-210. The higher activity of Th-230 could result from acid attack upon secondary thorium precipitates found on the tailings solid phase and formed in the mill. It is not possible to analyze for a similar difference between Th-232/Th-228 and Ra-228 due to the poor detection limit for Ra-228 in many samples, although the range of values suggest a similar range of values for Th-228/Th-232 and Ra-228.

6.0 BIOLOGY

6.1 Overview of Biology Component

The primary objective of the biological data collection component of this study was to assemble information which could ultimately be used in computer modelling to predict the potential radionuclide or trace element transfer to humans through the consumption of fish, wildlife or vegetation which have been exposed to emissions or effluents from decommissioned uranium tailings facilities.

6.2 Study Components

The Lacnor tailings contain levels of pyritic minerals that in the presence of sufficient free oxygen will generate acid through microbial iron oxidation. This process which generates sulphuric acid in turn results in the solubilization and mobilization of radionuclides and trace elements at low pH levels. Deeper in the tailings, in the absence of free oxygen, other bacteria may derive energy from the system through the reduction of sulphate back to sulphide. In order to quantify the level of microbial activity responsible for these processes at various depths in the tailings, a series of microbiological studies were undertaken. These included:

- aerobic plate count
- anaerobic deep tube count
- sulphate-reducing bacteria count
- most probable number (MPN) sulphur oxidizers estimate, and
- MPN iron oxidizers estimate

Besides bacterial data, the detailed table of results (Appendix 4) provides descriptions of the texture and colour of tailings at each depth analyzed. These data are summarized in Table 6.1. There appear to be no trends in the numbers of bacteria by either depth or type of tailings material. The variation in numbers of colonies between successive layers in the tailings is

Table 6.1

SUMMARY OF BACTERIAL SAMPLING

Bacterial Type Studied	Range of Mean Number (or MPN)/g Media	Discernible Trend
Aerobic	< 100 to 3.2×10^{7}	no
Anaerobic	< 187 to 7.6×10^{7}	no
Sulphate	< 20 to $> 2.4 \times 10^{5}$	no
Sulphur Oxidizing	< 3 to 9.3×10^{3}	no
Iron Oxidizing	< 3 to $> 2.4 \times 10^{5}$	no

as great as 10^6 times. This variability was more pronounced in one core (No.4) than the other (No. 5). In Core 4, the greatest variability was between the two bottom substrate samples of silty-sand and gravel till.

6.3 Vegetation

Six vegetation community types were identified and sampled at the Lacnor tailings site in the late summer of 1985:

- Birdsfoot Trefoil
- Cattail
- Red Fescue
- Reed Canary Grass
- Wild Red Raspberry, and
- Bare Unvegetated.

Samples of vegetation from quadrats in two communities were oven-dried, weighed and recorded as dry weight/m^2. The results are summarized in Table 6.2.

Radionuclide and Heavy Metal Analysis of Vegetation

Twenty-six composite samples of vegetation were collected from the five plant communities in the vicinity of the Lacnor tailings during the period July 29 to August 1, 1985. Samples were washed in tap water, rinsed with distilled water, air-dried and sent to the laboratory where they were oven-dried prior to analyses.

Table 6.3 summarizes results for radionuclide analyses.

Table 6.4 summarizes results for metal analyses.

Detailed analytical results are presented in Appendix 4, along with field, laboratory and quality control procedures.

Table 6.2

VEGETATION BIOMASS

Vegetation Community Type	Number of Replicates	Biomass (g dry wt/m^2) Mean	Biomass (g dry wt/m^2) Range	Standard Deviation
Birdsfoot Trefoil (1)	16	276.2	32.7-919.7	238.4
Fescue Grass	17	38.4	0-107.5	29.3
Birdsfoot Trefoil (2)	10	580.0	204.1-999.6	250.8

Table 6.3

SUMMARY OF RADIONUCLIDE ANALYSES OF VEGETATION FROM LACNOR TAILINGS

(radionuclide/g dry weight of vegetation)

Community	Number of Samples	Range of Values					
		U-238 (ug/g)	Ra-226 (Bq/g)	Th-228 (Bq/g)	Th-230 (Bq/g)	Th-232 (Bq/g)	Po-210 (Bq/g)
Birdsfoot Trefoil	8	<0.01-0.21	0.058-1.590	0.002-0.012	0.007-0.039	0.002-0.012	0.02-0.16
Cattail	2	0.12-0.17	0.090-0.536	0.002-0.006	0.022-0.030	0.002-0.006	0.02-0.06
Red Fescue-Birdsfoot Trefoil	5	0.02-0.27	0.236-1.103	0.004-0.010	0.016-0.037	0.004-0.010	0.04-0.18
Reed Canary Grass	1	0.14	0.196	0.006	0.035	0.006	0.02
Wild Red Raspberry	2	0.02-0.05	0.008-0.030	0.006	<0.005	0.006	<0.01
Townsite	3	0.02-0.07	0.012-0.217	0.005-0.006	<0.005-0.016	0.005-0.006	<0.01-0.01

TABLE 6.4: SUMMARY OF METALS ANALYSIS OF VEGETATION FROM LACNOR TAILINGS AREA (ug/g dry weight)

Community	No. of Samples	Aluminum	Arsenic	Barium	Beryllium	Boron	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
1. Birdsfoot Trefoil	4	11.4 to 161	0.03 to 0.14	1.1 to 11.5	L 0.02	2.4 to 8.1	L 0.5 to 0.6	1,890 to 13,200	L 0.5 to 0.6	L 3 to 3	7.7 to 18.0	37.0 to 247	L 3 to 20	1,410 to 2,590
2. Cattail	2	30.4 to 33.1	0.16 to 0.20	0.4 to 2.2	L 0.02	3.4 to 4.4	L 0.5	3,480 to 7,210	L 0.5 to 0.8	L 3 to 4	2.1 to 5.4	86.5 to 1,050	L 3	1,250 to 1,950
3. Red Fescue-Birdsfoot Trefoil	4	23.4 to 130	0.07 to 0.24	1.8 to 16.5	L 0.02	2.1 to 6.7	L 0.5 to 0.5	1,800 to 5,430	L 0.5 to 0.8	L 3 to 6	8.6 to 19.7	47.6 to 565	L 3 to 3	1,470 to 2,860
5. Wild Red Raspberry	1	67	0.05	14.5	L 0.02	6.2	0.7	2,290	L 0.5	L 3	14.2	36.0	L 3	1,470
Townsite	3	19.6 to 105	0.03 to 0.05	7.5 to 37.8	L 0.02	4.7 to 9.1	L 0.5 to 0.8	2,380 to 9,640	L 0.5 to 0.7	L 3	6.4 to 18.9	29.3 to 91.2	L 3	994 to 1,580

Community	No. of Samples	Manganese	Molybdenum	Nickel	Potassium	Phosphorus	Selenium	Silver	Sodium	Strontium	Titanium	Vanadium	Zinc	Zirconium
1. Birdsfoot Trefoil	4	9.5 to 115	L 10 to 30	4 to 8	6,550 to 16,500	1,560 to 2,500	0.08 to 0.48	L 0.3 to 0.6	L 50	2.02 to 7.16	0.9 to 6.4	L 0.3 to 0.8	11 to 62	L 3
2. Cattail	2	211 to 338	L 10 to 10	L 3 to 6	17,400 to 19,500	1,080 to 1,430	0.15 to 0.81	0.6 to 1.0	180 to 310	6.11 to 7.51	0.4 to 0.5	L 0.3	9 to 11	L 3
3. Red Fescue-Birdsfoot Trefoil	4	35.2 to 183	L 10	3 to 4	8,700 to 9,860	920 to 2,560	0.12 to 0.81	L 0.3	L 50	1.21 to 2.93	0.6 to 6.3	0.4 to 0.8	11 to 49	L 3
5. Wild Red Raspberry	1	114	10	4	8,850	1,960	0.02	L 0.3	70	12.9	0.7	0.9	24	L 3
Townsite	3	27.9 to 1,270	L 10	3 to 7	8,460 to 21,300	1,160 to 2,420	L 0.01 to 0.04	L 0.3 to 0.7	L 50 to 4,420	9.31 to 41.7	0.3	L 0.3 to 1.0	16 to 33	L 3

L = less than.

6.4 Soils

Soils samples were collected from the root zone (5 to 15 cm deep) in the Birdsfoot Trefoil (1) and Red Fescue-Birdsfoot Trefoil (3) communities. Sampling was during the July 29 to August 1, 1985 field program. Samples were air-dried in the field, shipped to the laboratory and oven-dried prior to analysis.

Table 6.5 presents results of soils analyses for radionuclides, while Table 6.6 presents results for metals analyses.

6.5 Wildlife

Five beavers were collected from area trappers over the summer of 1985. Flesh and molar samples were taken by Mr. R. Lipinski of Rio Algom Limited, frozen and shipped on ice to the laboratory for radionuclide analyses. (see Appendix 4 for details on methods). Beaver sex, weight and trapping location were documented by Rio Algom. Ages were estimated by Mr. M. Novak, Fur Services Coordinator, Ontario Ministry of Natural Resources.

Tables 6.7 provides the results of beaver sample analyses.

Table 6.5

RADIONUCLIDE ANALYSIS OF SOILS FROM LACNOR

Sample Number	Root Zone		U-238 (ug/g)	Ra-226 (Bq/g)	Th-228 (Bq/g)	Th-230 (Bq/g)	Th-232 (Bq/g)	Pb-210 (Bq/g)
L-27	(3)	Red Fescue	6.0	3.87	0.07	0.62	0.07	1.25
L-28	(1)	Birdsfoot Trefoil	6.5	2.18	0.07	0.41	0.07	1.15

TABLE 6.6: METALS ANALYSES RESULTS FOR SOILS FROM LACNOR (ug/g)

Sample No.	Plant Community	Aluminum	Arsenic	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Molybdenum
L-27	(3) Red Fescue	25,300	3.72	0.47	L 1	1,130	235	L 5	18.4	5,440	135	1,250	16	L 20
L-28	(1) Birdsfoot Trefoil	25,200	3.86	0.54	L 1	1,270	252	5	22.6	5,660	160	1,390	17	L 20

Sample No.	Plant Community	Nickel	Phosphorus	Potassium	Selenium	Silver	Sodium	Strontium	Thorium	Titanium	Vanadium	Zinc	Zirconium
L-27	(3) Red Fescue	L 5	120	18,700	0.538	L 0.5	500	17.8	36	849	17.7	15	69
L-28	(1) Birdsfoot Trefoil	6	150	18,000	0.577	L 0.5	500	18.0	51	945	18.6	15	52

TABLE 6.7: RESULTS OF RADIONUCLIDE ANALYSES OF BEAVER SAMPLES FROM LACNOR AREA

(Results reported on a wet weight basis)

Beaver No.	Location Trapped	Sex	Age (yr)	Wet Weight (kg)	% Water	U-238 (ug/g)	Ra-226 (Bq/g)	Th-228 (Bq/g)	Th-230 (Bq/g)	Th-232 (Bq/g)	Pb-210 (Bq/g)
1	West Nordic Pond	M		12.3	78.0	0.0014	0.002	L 0.0003	L 0.0003	L 0.0003	0.001
2	Sheriff Creek Park	F		14.5	75.4	0.0059	0.0026	L 0.0003	0.001	0.0007	L 0.001
5	Elliot Lake Area Pond	F		14.5	60.9	0.0015	0.0019	0.0003	0.0003	0.0004	0.003
6	Elliot Lake Area Pond	M		11.3	70.8	0.0018	0.0014	L 0.0003	0.0008	L 0.0003	0.002
7	Elliot Lake Area Pond	M		12.7	55.8	0.0007	0.0006	0.0003	0.0003	L 0.0003	L 0.001

L = less than.

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LACNOR FIELD STUDY
ELLIOT LAKE, ONTARIO

APPENDIX 1
GEOHYDROLOGY AND GEOCHEMISTRY

Prepared for

The National Uranium Tailings Program

By

Golder Associates

Beak Consultants SENES Consultants

Cumming - Cockburn & Associates

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APPENDIX 1 GEOHYDROLOGY AND GEOCHEMISTRY

1.1 Introduction

1.1.1 Scope and Objectives

In December, 1984, Golder Associates, SENES Consultants Limited, BEAK Consultants and Cumming-Cockburn & Associates Limited were awarded a contract by the National Uranium Tailings Program to carry out the field study at the Lacnor uranium tailings area in Elliot Lake, Ontario. The intent of the project, as set out in the terms of reference was:

> "The design and operation of a sampling program, incorporating chemical, physical and biological data that will be used to characterize the Lacnor tailings and environs, and which will provide raw data for the study of processes involving tailings constituents and their pathways".

The field study therefore required the sampling of tailings solids, subtailings soil and rock, the surrounding soil and rock, tailings porewater, groundwater, surface water, the measurement of surface water runoff, the gathering of atmospheric data and a biological assessment of the site.

This appendix (Appendix 1 to the main overview report) includes details regarding the geohydrology and geochemistry of the Lacnor uranium tailings area and details of all geohydrological and geochemical work carried out in the field, field quality assurance methods and all results. It is intended to be a factual report. Although reference is made to the results and potentially erroneous results, an overall interpretation of the factual results was specifically excluded from this study.

Other appendices to the main report cover the detailed results regarding meteorology and air quality (Appendix 2), surface water (Appendix 3), biology (Appendix 4) and the detailed methods of laboratory analysis (Appendix 5).

Chemex Labs Ltd. of Vancouver, British Columbia, were retained as the prime laboratory for radiological testing of tailings solids samples and samples of porewater/groundwater, while Monenco Analytical Laboratories of Calgary were retained to perform check analyses on selected samples. Barringer Mayenta Limited of Rexdale, Ontario was retained as the prime laboratory for all other chemical testing, with check testing carried out by Beak Analytical Services of Mississauga, Ontario. All geotechnical testing was carried out at Golder Associates' Mississauga laboratory.

1.1.2 Appendix Outline

This appendix is organized into the following sections:

1.2 Geology, presents an overview of the regional geology of the Elliot Lake area and of the Lacnor basin based on observations made during a reconnaissance survey.

1.3 Tailings Solids, presents the results of investigations regarding the tailings solids (grain size, permeability, geochemistry) from boreholes put down across the tailings area, and grab samples collected from the surface of the tailings area during the reconnaissance survey. This section also includes the results of the boreholes which were extended down into the overburden and bedrock beneath the tailings.

1.4 Off-Tailings Rock, presents the results of boreholes put down in fault zones around the tailings area.

1.5 Porewater/Groundwater, presents the results of geohydrological investigations regarding tailings porewater and groundwater under and outside the tailings area, including water levels in monitoring wells installed in and beneath the tailings, hydraulic conductivity measurements and the chemical analysis of water samples obtained from the monitoring wells.

1.1.3 Schedule of Events

The reconnaissance survey of the tailings basin and surrounding area was conducted in November, 1984. A total of thirty-six boreholes were put down at five locations of the tailings in March/April, 1985. At two of these locations, the deepest boreholes were drilled into the bedrock beneath the tailings, while at the other three locations, the deepest boreholes were advanced until refusal on what was inferred to be the top of bedrock. Thirty-six monitoring wells were installed in separate boreholes during the tailings drilling program, most within the tailings but others in the sub-tailings natural soils and bedrock.

Inclined boreholes were drilled into the rock in two stream valleys south of the tailings area and nine monitoring wells were installed in June, 1985.

Monthly water levels were read between March and October, 1985. In situ hydraulic conductivity tests (generally rising head tests) were conducted in June, 1985. Tailings porewater and groundwater samples were collected in June and August, 1985. The majority of samples were taken from two monitoring stations, one in sandy tailings and one in interlayered fine and coarse tailings, but groundwater samples were also collected from piezometers installed beneath the tailings in the underlying natural subsoils and bedrock and in the off-tailings rock holes.

1.2 Geology

1.2.1 Regional Geology

The Elliot Lake mining area is located in north-central Ontario at about longitude 82 degrees 36 minutes west, latitude 46 degrees 24 minutes north. The topography is fairly characteristic of the Canadian Shield and may be described as rugged but of relatively low relief with elevation differences being generally in the order of 30 to 60 m or less. Topographic highs typically consist of rock knolls or ridges and topographic lows generally contain abundant swamps, lakes or streams (Davis et al., 1979). The topography is dominantly controlled by the structural orientations in the underlying bedrock.

The underlying bedrock is largely Lower Proterozoic age metasediments comprised of quartzite, arkose, conglomerate and minor argillaceous strata. These rocks have been folded into a broad, westward plunging syncline some 8 to 10 km in width known as the Quirke Syncline (Robertson, 1968). The Lacnor Mine is located on the south limb of the syncline. The folded metasedimentary strata are cross cut by intrusive diabase sills and dykes (Nipissing Diabase) and faults (Robertson, 1968).

Regional fault structures are oriented both northwest-southeast and east-west. These features tend to occur at 5 to 6 kilometre intervals. Smaller scale faulting tends to be more intense (1 to 2 features per square kilometre) and, while generally steeply dipping, exhibit variable strike and persistence. Intruded diabase dykes are commonly associated with regional faulting, particularly those oriented northwest-southeast.

Overburden is largely restricted to topographic lows and, with the exception of recent bog or swamp deposits, consists predominantly of fluvial or outwash silty sands and gravels of glacial outwash origin. Local deposits of essentially cohesionless silty to sandy till also occur in topographic lows or plastered on the flanks of bedrock highs. The permeability of the till is typically in the order of 10^{-4} to 10^{-5} cm/s.

Groundwater appears to occur as a complex series of local "perched" regimes associated with the lake systems. The majority of groundwater transport between these local regimes occurs through overburden-infilled bedrock lows or major discontinuities (e.g. faults) in the rock. However, the results of mining experience and geotechnical borings in the Elliot Lake area suggest that the permeability of the faults at depth is generally low, typically less than about 10^{-5} cm/s.

1.2.2 Geology of the Lacnor Basin

The Lacnor Tailings Basin is situated within a bedrock valley formerly occupied by wetlands. The present elevation of the tailings surface is approximately 380 m above sea level. Ponded water currently covers the surface of the tailings in the east end of the basin (see Figure 1.1).

The basin is surrounded by ridges of exposed bedrock that trend east-west, subparallel to the strike of the bedrock. The ridge along the north side of the basin rises in south-facing, near vertical cliffs to elevations of 420 to 440 m. The lower half of the south facing slope is partially covered by talus. The ridge along the south side of the basin is less pronounced and rises to elevations of 400 to 410 m. It separates the Lacnor Basin from the Nordic Basin to the south which occurs at an elevation of approximately 340 m. The ridge is cut by north-south and northwest-southeast trending valleys that form the drainage pathways from the basin.

The Lacnor Tailings Basin is largely underlain by quartzite metasedimentary rock of the Upper Mississagi formation. The quartzite is a light grey to pinkish grey coloured, medium to thickly bedded rock that strikes east-west and dips northward at 15 to 20 degrees. This quartzite comprises the structurally controlled dip and scarp ridges that separate the Lacnor and Nordic Tailings Basin.

The steep ridges along the north side of the Lacnor Tailings Basin are comprised of intrusion diabase sills. The sills dip northward subparallel to the dip of the metasedimentary rocks. A large diabase dyke, trending northwest-southeast occurs along the eastern side of the basin, accompanied by a smaller northerly trending, diabase dyke (see Figure 1.1).

The Pecors Lake Fault, a major northwest-southeast trending structure passes diagonally through the central portion of the tailings basin and erosion of fractured rock associated with this feature has created the valley below the east dam (see Figure 1.1). Faulting and fracturing associated with this fault was encountered in Boreholes SO-05 and SO-07. Diabase dyking is also associated with the Pecors Lake Fault as noted by diabase encountered in Borehole SO-07. The large northwest-southeast trending diabase dyke that occurs along the eastern side of the basin is also considered to be related to the same structural episode as the Pecors Lake Fault. Both the faulting and parallel diabase dyking appear to post-date the instrusion of the massive diabase sills along the northern rim of the tailings basin.

Jointing within the rock, based on an examination of exposed surfaces, tends to comprise widely spaced, linear, smooth surfaced features. Three main joint sets have been identified, J1, J2 and J3, as shown on the stereonet inset on Figure 1.1. The J1 and J2 sets are the dominant joint systems. The J1 set dips from 60 to 90 degrees towards the southwest and strikes subparallel to the Pecors Lake Fault. The J2 set dips 60 to 90 degrees toward the south, parallel to the bedding and perpendicular to the dip of the rock strata. The J3 set is a less prominant, conjugate set that dips 80 to 90 degrees towards the east and west. It may be structurally associated with the north-south trending linear fault valleys within the rock such as the valley that extends southward from the eastern half of the Lacnor Tailings Dam to the Nordic Tailings Area.

1.3 Tailings Solids

1.3.1 Reconnaissance Survey and Surface Samples

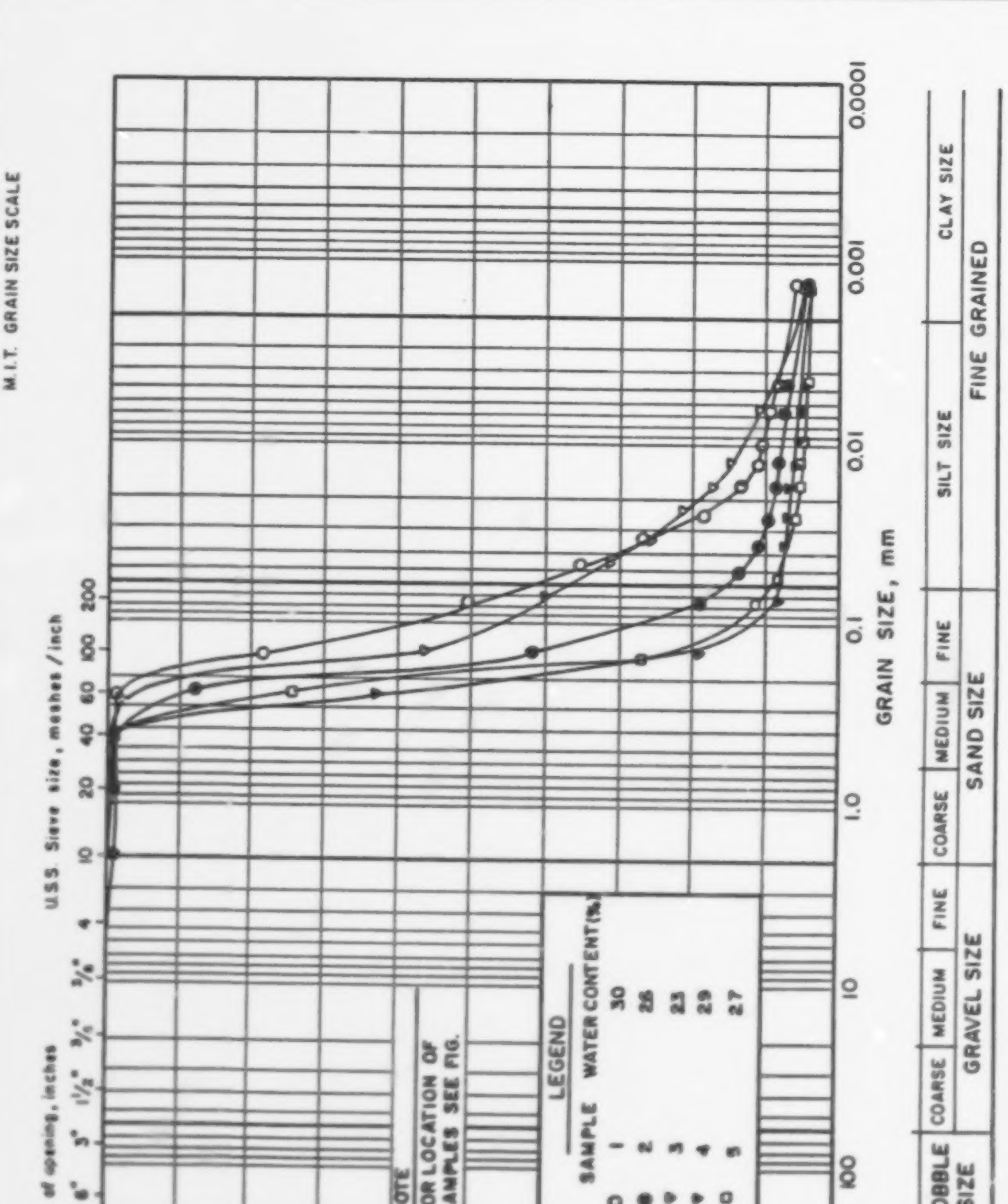
Ten surficial grab samples of tailings (GS1-10) were obtained across the Lacnor tailings area during the site reconnaissance between 13 and 16 November 1984 (for locations see Figure 1.1). The samples were bagged and shipped to Golder Associates' Mississauga laboratory for analysis. The results of water content and gradation analyses on these samples are shown on Figures 1.2 and 1.3.

The water content of the surficial grab samples ranged from 23 to 33 per cent. The grain size distribution analyses varied from sand with a trace of silt

GRAIN SIZE DISTRIBUTION
SURFACE GRAB SAMPLES OF TAILINGS GS. 1 to 5

FIGURE 1.2

PROJECT No. 841-1341



Form G.A.-D-7 (a)

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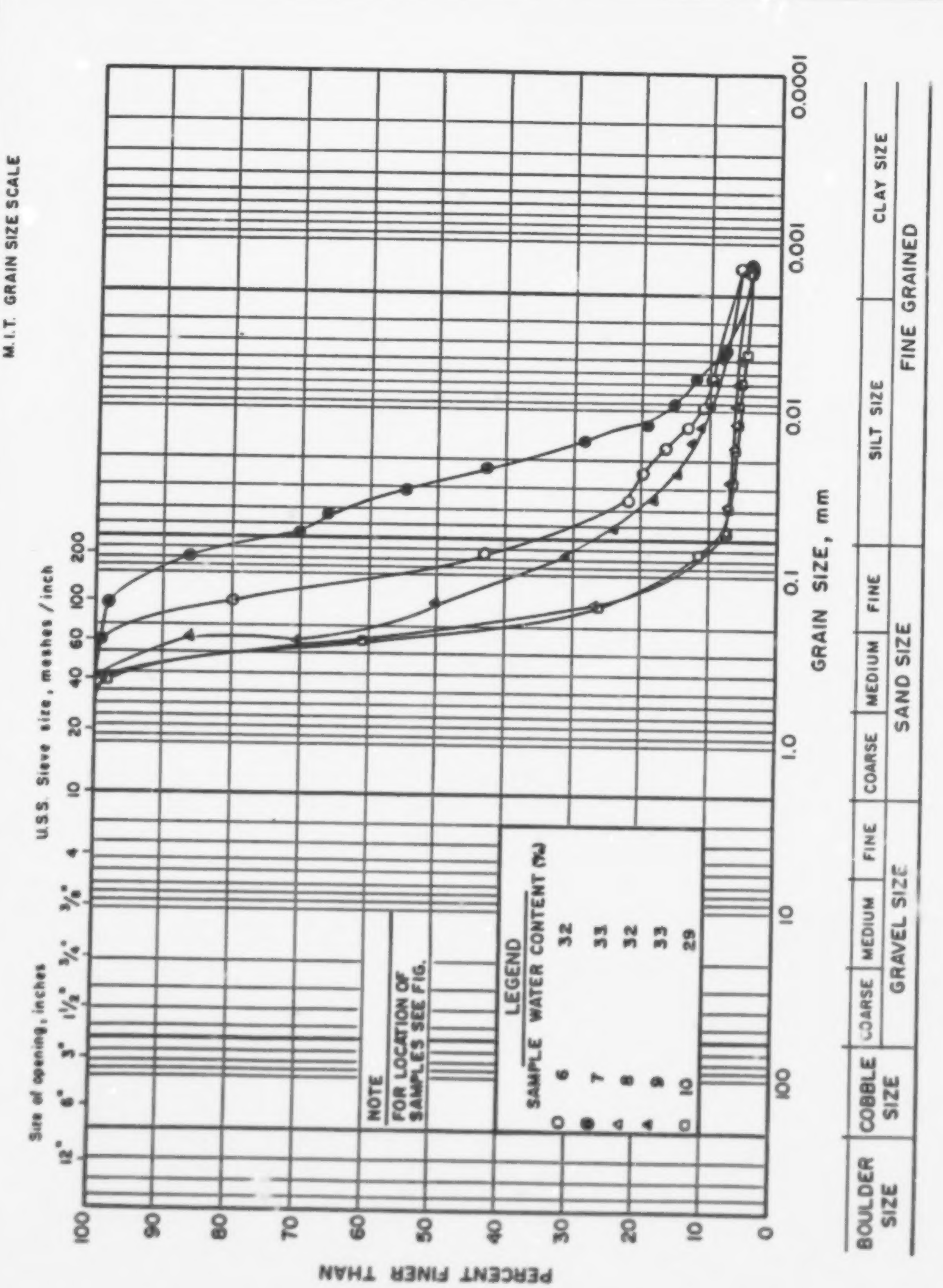
PROJECT No. 841-1341

GRAIN SIZE DISTRIBUTION
SURFACE GRAB SAMPLES OF TAILINGS GS-6 to 10

FIGURE 1.3



Form G.A.-D-7 (m)

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(samples 4, 5, 8 and 10, all located along the northern half of the tailings basin) to silty sand (samples 1, 3, 6 and 9, all located in the eastern and southern portions of the tailings basin) to the finest sample of all, sample 7, from the southern part of the tailings basin, which was classified as a sandy silt.

1.3.2 Boreholes in Tailings Area

Boreholes were put down at five locations across the tailings area between 19 March and 3 April 1985 (for locations of Boreholes SO-01 to SO-05, see Figure 1.1). The locations of the boreholes were selected to include areas of coarser sand tailings towards the western end of the basin and areas of finer tailings in the eastern and southeastern parts of the basin. Borehole SO-05 was located above an expected bedrock fault zone and borehole SO-01 was located above an area where unfaulted rock was anticipated.

At each location a series of boreholes were drilled to various depths. The number of boreholes in each nest was based on the material encountered in the initial borehole. Subsequent to the soil sampling program, piezometers were installed in each borehole. During the remainder of the field study groundwater samples were collected from selected piezometers and water levels were measured in designated piezometers. Each borehole was assigned a letter suffix for identification purposes and Table 1.1 provides a summary of the information pertaining to each of the boreholes.

The drilling was carried out using a Nodwell mounted CME 75 which was supplied and operated by All Terrain Drilling Limited, a specialist drilling contractor from Waterloo, Ontario. The drilling was carried out under the full-time supervision of an engineering geologist from Golder Associates. The elevations of the ground surface at each borehole were determined by Kenting Earth Sciences Limited in May 1985.

Table 1.1 - BOREHOLE INFORMATION SUMMARY

Site ID	Borehole Suffix	Borehole Depth (m)	Soil Samples (Number Collected)	Groundwater Sample (Number Collected)	Water Level Measurements
01	a	7.8	13	1	6
	b	11.8	1	2	6
	c	6.5	6	-	6
	d	4.2	-	-	6
	e	2.6	-	1	6
	f	1.2	-	1	6
02	a	16.1	13	2	6
	b	14.5	-	2	6
	c	10.4	-	2	6
	d	2.6	2	1	6
	e	1.0	-	2	6
	i	7.9	-	2	4
	ii	7.5	-	2	4
	iii	6.6	-	2	4
	iv	5.5	-	2	4
	v	3.6	-	2	4
	vi	4.6	-	2	4
	vii	2.6	-	2	4
	viii	1.5	-	2	5
03	a	12.3	20	-	6
	b	10.5	6	1	6
	c	9.0	-	-	6
	d	7.7	-	1	6
	e	6.1	-	1	6
	f	4.6	-	1	6
	g	3.1	-	1	6
	h	1.0	-	-	6
04	a	11.9	18	2	6
	b	8.8	3	-	6
	c	7.3	1	1	6
	d	6.2	-	-	6
	e	4.1	-	1	6
	f	2.8	-	1	6
	g	1.3	-	-	6
05	a	18.3	1	2	5
	b	28.4	39	2	5
	c	22.1	-	2	5
	d	10.9	-	2	5
	e	9.2	-	2	5
	f	8.0	-	2	5
	g	-	6	-	-
	h	6.1	-	2	5
	i	4.3	-	2	5
	j	2.8	-	2	5
	k	1.1	-	1	5
Pond	-	-		-	-
06	a	31.2	-	-	4
	b	16.4	-	1	4
	c	8.8	-	1	4
07	a	3.8	-	-	4
	b	17.9	-	1	4
	c	3.4	-	-	4
	d	15.7	-	1	4
	e	8.6	-	-	4
	f	9.4	-	1	4
08	lake	-	-	1	-

1.3.3 Borehole Sampling Techniques

At each of the five borehole locations in the tailings area, an initial borehole was advanced vertically through the tailings using 15.9 cm I.D. hollow stem augers to refusal on what was presumed to be the underlying bedrock. A 9.0 cm I.D. continuous sampler was employed throughout the advance through the tailings and this provided an 8.26 cm diameter continuous core from the surface down to the base of the tailings. The run lengths varied between 0.76 m and 1.5 m, depending on ground conditions. The initial boreholes at each location were labelled with the suffix "a".

Standard 5.08 cm O.D. split spoons were used to recover samples from the dense till and cohesionless strata below the tailings. Standard penetration tests were conducted through the tailings at two sites, Boreholes SO-01 and SO-04 and in the natural strata underlying the tailings in all holes. Although the standard penetration tests permitted an evaluation of in-place density of the tailings, sample recovery using the split spoon sampler was poor in both the till (due to the very stoney nature of the till) and the overlying tailings (even with a sample retainer in the shoe of the sampler).

The samples recovered from the initial boreholes at each location were examined and logged and appropriate jar or bag samples collected for selected laboratory testing. Aided by the knowledge of the stratigraphy gained at the initial hole, additional undisturbed tube samples were collected at selected horizons during the augering of subsequent adjacent holes at each location for the installation of piezometers. These samples were collected either in 7.6 cm diameter by 0.76 m long PVC plastic liner sleeves in the continuous sampler or in standard 5.08 cm diameter steel Shelby tubes. All tube samples were sealed at both ends with wax, capped on site and stored with the other samples at temperatures slightly above freezing. The subsequent holes were labelled with the suffixes "b", "c", "d", etc. at each borehole location according to the sequence in which they were drilled.

Two of the boreholes, SO-01b and SO-05a, were advanced up to 7.4 m into the underlying bedrock using N-sized diamond coring equipment. The rock core was examined and logged on site and stored in the site trailer.

The details of each boring are summarized on the Record of Boreholes following the text of this appendix. In all, a total of 130 samples were collected during the investigation. The samples are briefly described and listed in tabular form following the Record of Boreholes.

1.3.4 Borehole Sampling Quality Assurance

All sampling equipment was cleaned between boreholes to minimize potential cross contamination. In addition, any sampler which was to be used to take a sample of natural subsoils below the tailings was washed with water from Dumbell Lake prior to sampling. When a borehole was being advanced solely through tailings, the split spoon sampler was brushed clean prior to re-use down the borehole.

Prior to collecting a jar or bag sample, any smear along the outside of the sample was carefully removed with a knife and not retained as part of the sample.

Even though the Shelby tube samples were waxed and capped at both ends, it was difficult to maintain a tight seal and some porewater drained from several of the Shelby tube samples during subsequent transport. The water contents of these samples are therefore likely to be too low.

Water from Dumbell Lake was used while drilling the bedrock in Boreholes SO-01b and SO-05b beneath the tailings, as well as during the coring of the boulder in Borehole SO-02a.

It is believed that part of a discontinuous bog that must originally have existed in the basin was encountered at SO-05, and that the natural strata beneath the peat could be "open" to tailings leachate outside the immediate borehole locations.

All soil samples were kept sealed and transported directly to Golder Associates' Mississauga laboratory where the samples were re-examined and representative samples submitted for geotechnical, radiological or chemical testing.

1.3.5 Subsurface Conditions

Detailed logs of the subsurface conditions encountered in the boreholes put down in the Lacnor tailings basin are summarized on the Record of Boreholes following the text of this appendix.

The materials encountered in the boreholes may be divided into the following three main categories:

i) tailings
ii) sub-tailings soils
iii) bedrock

Each of these categories is described in detail below.

i) Tailings

Between 7.9 m and 15.1 m of tailings were encountered at the five borehole locations across the tailings. The tailings were thickest at Borehole SO-02 and thinnest in the western end of the basin at Borehole SO-01.

Two distinct types of tailings were encountered. The coarser type consisted of fine to medium sand with some silt (10 to 20 per cent silt) while the finer type generally consisted of silt sized tailings with a trace to some sand (1 to 20 per cent sand). Generally the two material types were distinct when observed in the field.

The finer type of tailings was found to be absent at SO-01 and 02, situated in the western portion of the basin. Boreholes at SO-03, 04 and 05 located in the eastern portion of the basin encountered interlayered fine and coarse tailings throughout most of their depths. However, the coarser sand was present as a 1.1 to 2.7 m thick surface layer of tailings in these eastern three boreholes.

The finer silt tailings ranged from light to very dark grey to black in colour and were always found in a saturated condition. The coarser sand tailings varied from light to dark grey, below the static water table, to a very light grey to beige colour, above the water table in the oxidized zone. This zone varied in thickness between about 0.46 to 0.91 m. At SO-03, the coarser sand tailings varied from light to dark reddish brown in colour in the oxidized zone.

Pyrite was visible in most samples originating below the water table but was virtually absent in the oxidized zone that generally occurred within the upper 1 to 1.6 m of tailings.

Standard penetration tests carried out through the tailings at SO-01 and SO-04 indicated that the tailings ranged between loose and very loose in density.

ii) Sub-tailings Soils

Four types of sub-tailings soils were identified. They included topsoil, till, peat, and glaciofluvial material such as sands, silts and gravels. The soil types are described below.

Topsoil was encountered at all but the SO-05 site. Its thickness ranged from between just a trace on the sampling equipment to a maximum of 0.15 m at SO-04. The topsoil contained varying amounts of humus and was generally found to be dark brown to black silty sand and gravel with cobbles.

A relatively thin layer of till was encountered in all boreholes. It ranged in thickness from 0.31 to 2.43 m. The till was found to be a very dense, medium grey to dark brown silty sand and gravel with cobbles and boulders. The extreme coarseness of the till was evident in the borehole at SO-02a where a 0.6 m thick quartzite boulder was cored and found to be underlain by a further 1.2 m of till. Further evidence as to the coarse nature of the till was observed in the exposed wall of the drainage ditch near surface water monitoring location SW-03 at the east end of the basin. Although refusal occurred in the boreholes at SO-02a, 03a, 04 and 04a on what was inferred as being the top of bedrock, this could not be interpreted with total certainty as being bedrock.

Attempts were carried out to core the till in the borehole at SO-02a with rotary diamond equipment; however, due to the non-cohesive nature of the material, only the coarser rock fragments were recovered.

A distinct layer of peat encountered below the tailings of the SO-05 site ranged in thickness between 0.3 to 1.68 m. This variation occurred over a relatively short horizontal distance of less than 4.6 m. The variability of the peat thickness is most likely as a result of the presence of a ring bog and its associated floating peat mat that is known from the airphotos to have existed at this location prior to filling of the basin. The peat was found to be moist, relatively firm, uniformly dark brown and fibrous in nature throughout. A distinct peat layer was not present at the other borehole locations across the tailings.

Glaciofluvial materials ranging from silts to coarse sands and gravels were encountered below the peat in several boreholes at the SO-05 site. The total thickness of the glaciofluvial materials was approximately 7 m. Three types of materials which appeared to be continuous across the SO-05 site, but of varying thickness, were identified. Immediately below the peat was a 0.6 to 0.9 m thick layer of laminated light grey fine to medium grey, medium to coarse sand and gravel. This layer proved difficult to penetrate and sample. Sand and gravel materials repeatedly flowed up into the augers by some 4.5 to

6.0 m even when the water level inside the augers was kept equal to or above the water level in the tailings. The coarser gravel fragments were very angular in shape and of varied composition.

This sand and gravel layer was underlain at SO-05 by up to 3.7 m of compact to dense light grey silt with some fine to medium sand, (10 to 20 per cent sand) that looked very similar to the tailings encountered higher up the hole. The presence of the peat and glaciofluvial sands between this layer and the tailings and the high density of the sand indicated that the sub-peat materials were not tailings.

iii) Subtailings Bedrock

As noted previously, two boreholes at SO-01b and SO-05b were advanced 5.0 and 7.2 m, respectively, beyond auger refusal into the underlying bedrock using N-sized diamond coring equipment. The rock recovered from both holes was a slightly weathered, light to dark grey, medium to coarse grained quartzite. The rock core from SO-01b was found to be relatively intact, exhibiting moderately wide to wide joint spacing. It was apparently unstructured with no evidence of faulting. The majority of the of the joints appeared permeable to some extent due to the persistent penetrative weathering up to 12 mm deep visible along their surfaces.

The rock core from Borehole SO-05b exhibited a moderately narrow joint spacing and was broken by a near vertical 25 mm wide chlorite and breccia filled fault and a parallel series of joints. The majority of the joints were found to be faintly weathered.

1.3.6 Geotechnical Laboratory Results

Eighteen tailings and subtailings solids samples were subjected to geotechnical tests. The results are summarized on Table 1.2.

Fifteen gradation tests were carried out; the results are given on Figures 1.4

Table 1.2 - TAILINGS SOLIDS - SUMMARY OF GEOTECHNICAL LABORATORY TESTING - LACNOR

SITE	BOREHOLE	SAMPLE #	TYPE(1)	DEPTH (m)	SAMPLE DESCRIPTION	GRADATION	WATER CONTENT (%)	SPECIFIC GRAVITY	PERMEABILITY (cm/s)
SO-01	c	2	SS	1.2-2.4	SANDY TAILS	x (2)	28	-	2.7 x 10-3
SO-01	c	5	SS	5.8-6.4	SANDY TAILS	x (2)	25	-	9.1 x 10-4
SO-01	a	7	J	6.1-6.9	SANDY TAILS	x	20	-	-
SO-02	d	1	SS	0.3-0.9	SANDY TAILS	x	21	-	-
SO-02	d	2	SS	1.5-2.1	SILT & SAND TAILS	x	26	-	-
SO-02	a	3	PS	3.2-4.0	SANDY TAILS	x	20	-	-
SO-02	a	6	PS	7.8-8.5	SANDY TAILS	x	20	-	-
SO-02	a	8	PS	10.8-11.6	SANDY TAILS	x	21	-	-
SO-03	b	2	PS	4.0-4.7	SILT TAILS	x	63	-	1.1 x 10-5
SO-03	b	5	PS	7.2-7.9	SILT TAILS	x	69	2.59/2.60	9.6 x 10-6
SO-04	a	7	SS	7.3-7.9	SILTY TAILS	x (2)	36	-	-
SO-05	a	1	PS	0.9-1.7	SANDY TAILS	x	20	-	-
SO-05	g	1	PS	4.3-5.3	SILT TAILS	x	51	-	-
SO-05	g	3	PS	6.4-7.2	SILT TAILS	x	53	-	-
SO-05	g	4	PS	11.0-11.7	SAND & SILT TAILS	x	27	-	-
SO-05	g	5	PS	15.2-16.0	PEAT	-	203	-	-
SO-05	g	6	PS	16.0-16.8	SAND & SILT	x	21	-	-
SO-05	b	13	J	21.1-21.7	SILT	x	16	-	-

NOTES:
(1) SS - Steel Shelby
J - Jar
PS - Plastic Shelby
(2) Includes Duplicate Test run with Tailings Liquor

to 1.8. The results of the gradation tests were used to confirm the field description of the tailings and subtailings solids during drilling. As shown on Table 1.2 and Figures 1.4 to 1.8, the tailings varied from a sand with trace of silt at the western end of the basin (site SO-01 and SO-02) to predominantly silt sized material in the eastern and southeastern portion of the basin (Boreholes SO-03, 04 and 05). However, coarser sand tailings were also encountered within the tailings solids samples recovered from the three more easterly boreholes.

In addition to the standard gradation tests, some additional gradation tests were conducted in tailings liquor because tailings samples have a tendency to flocculate in distilled water, despite the addition of a deflocculating agent. As shown on Figure 1.4 and 1.6 there was relatively little difference between the results from standard gradation analyses and those run using tailings liquor for samples of sandy tailings, but there was some minor difference in the results of the standard and tailings liquor tests on silt tailings samples.

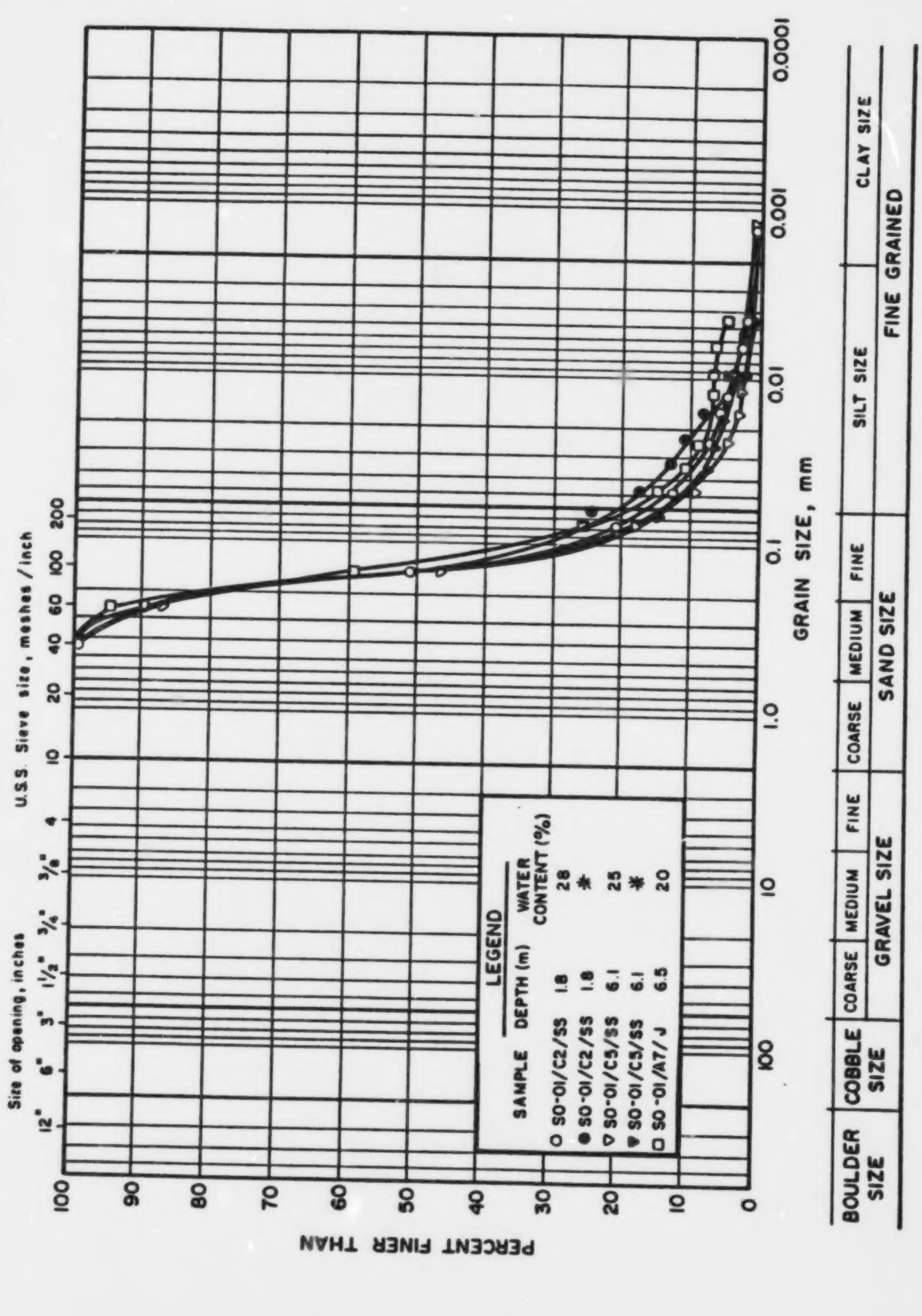
The water contents of the sandier tailings were generally in the range of 20 to 30 per cent, while those for the finer tailings varied from about 50 to 70 per cent. These values are consistent with other measurements in the Elliot Lake area but are towards the lower end of measured values. The results reported are overall water contents for any given sample. Variations in water content within samples are a function of layering of the tailings and can cause variations of up to ±2 to 3 per cent in sandy tailings and ±5 per cent in silty tailings.

Laboratory permeability tests on two undisturbed Shelby tube samples of sandy tailings from borehole at SO-01 gave vertical coefficients of hydraulic conductivity of 2×10^{-3} and 9×10^{-4} cm/s, while those on two samples of silt tailings from borehole SO-03 gave vertical permeabilities of 1×10^{-5} cm/s. These results are consistent with other measurements in the Elliot Lake area, although high in the range of past measurements.

GRAIN SIZE DISTRIBUTION
BOREHOLE SO-01 TAILINGS

FIGURE 1.4

PROJECT No. 841-1341



* DUPLICATE TEST IN TAILINGS LIQUOR

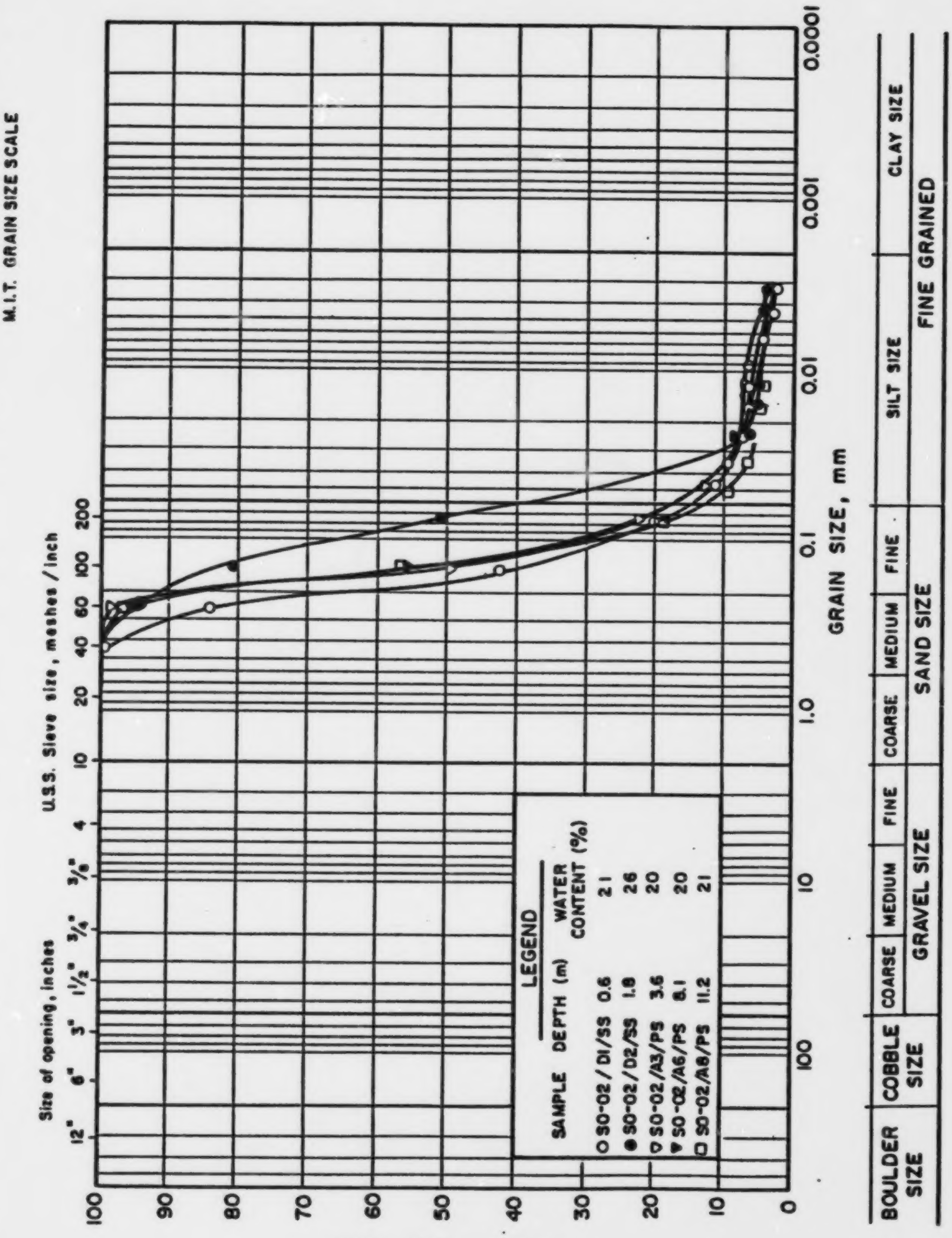
Form G.A.-D-7 (m)

Golder Associates

PROJECT No. 841-1341

GRAIN SIZE DISTRIBUTION
BOREHOLE SO-02 TAILINGS

FIGURE 1.5



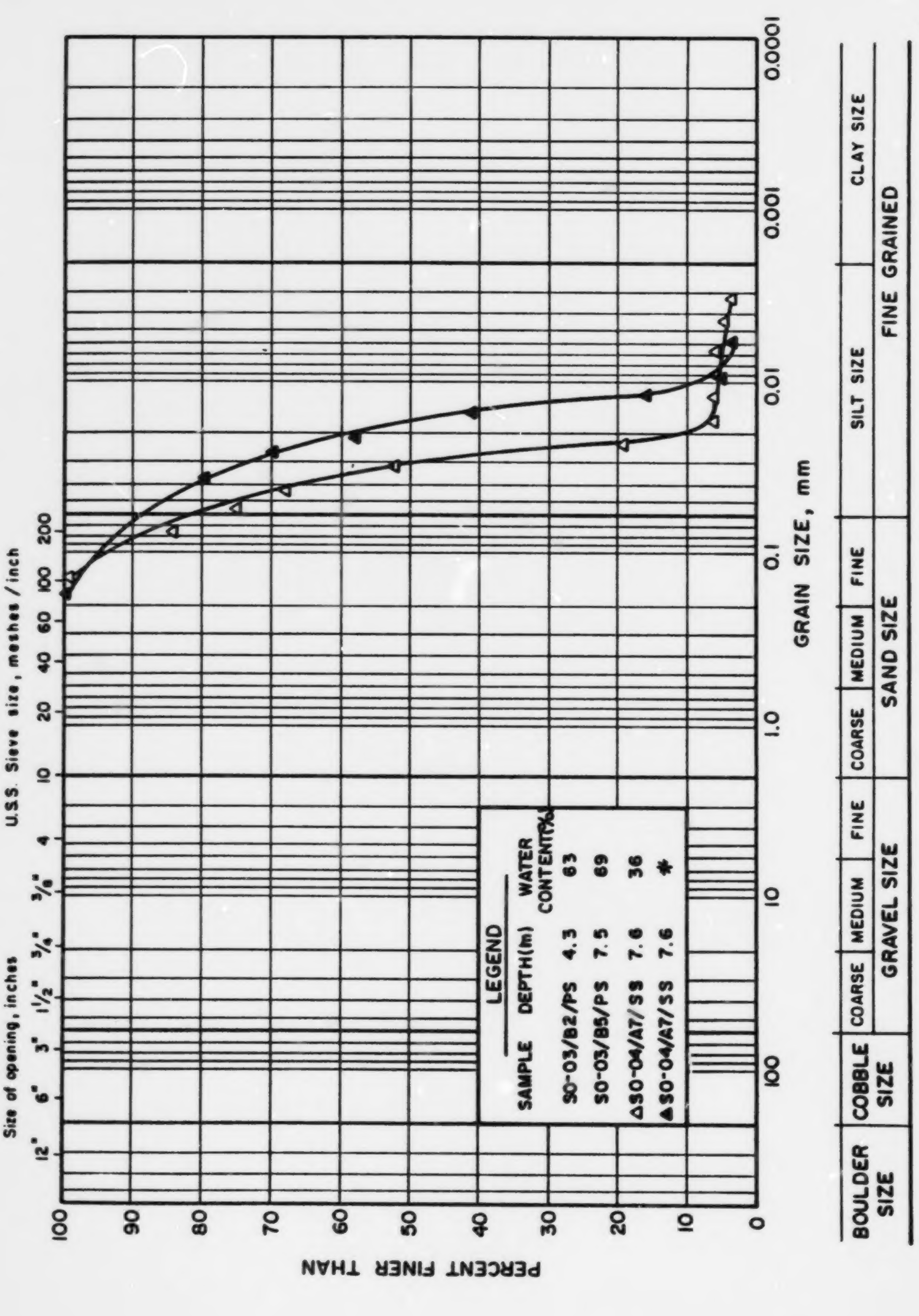
Form G.A.-D-6 (m)

Golder Associates

PROJECT No. 841-1341

GRAIN SIZE DISTRIBUTION
BOREHOLE SO-03 TAILINGS

FIGURE 1.6



* DUPLICATE TEST IN TAILINGS LIQUOR

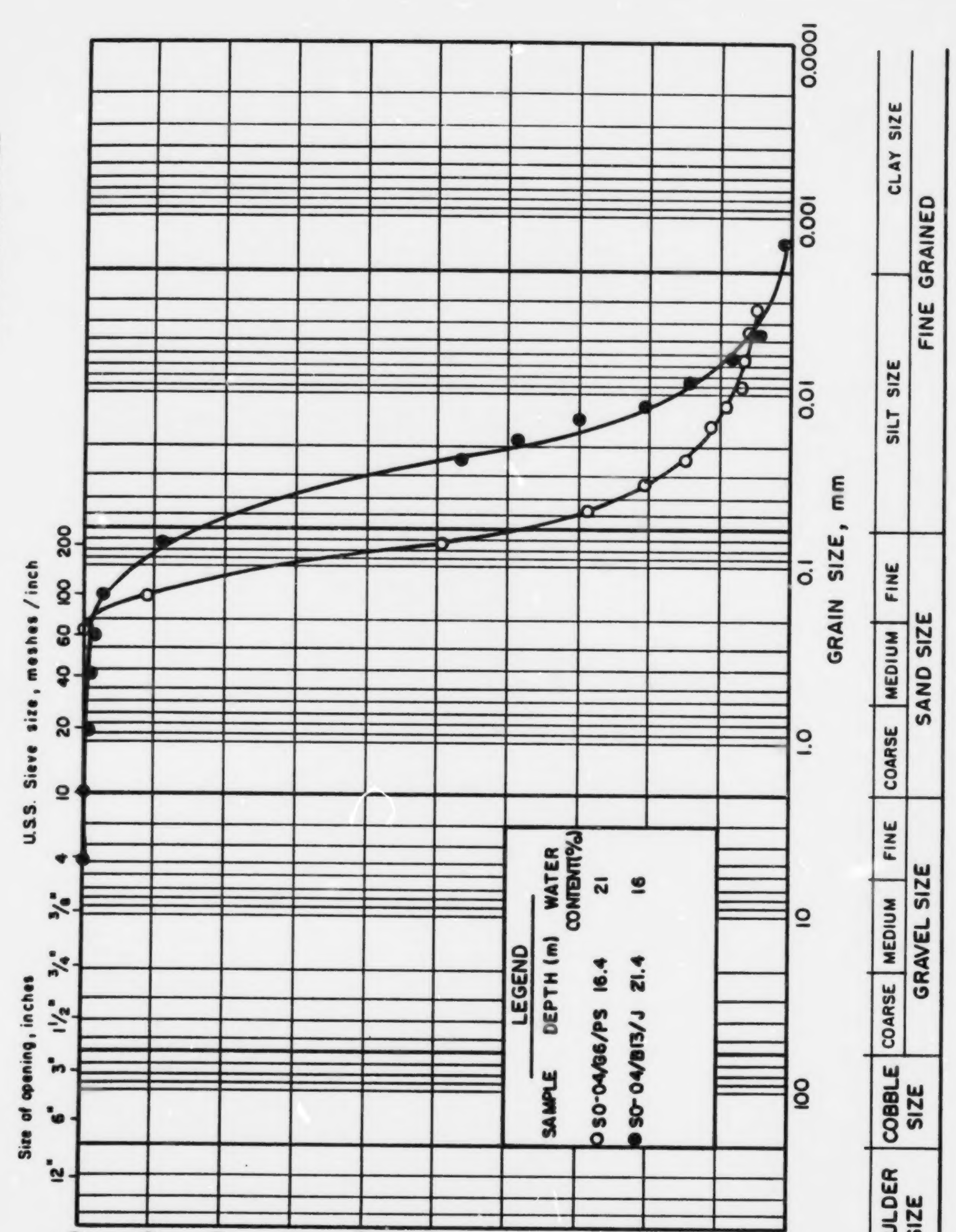
Form G.A.-D-6(m)

Golder Associates

PROJECT No. 841-1341

GRAIN SIZE DISTRIBUTION BOREHOLE SO-04 TAILINGS

FIGURE 1.7



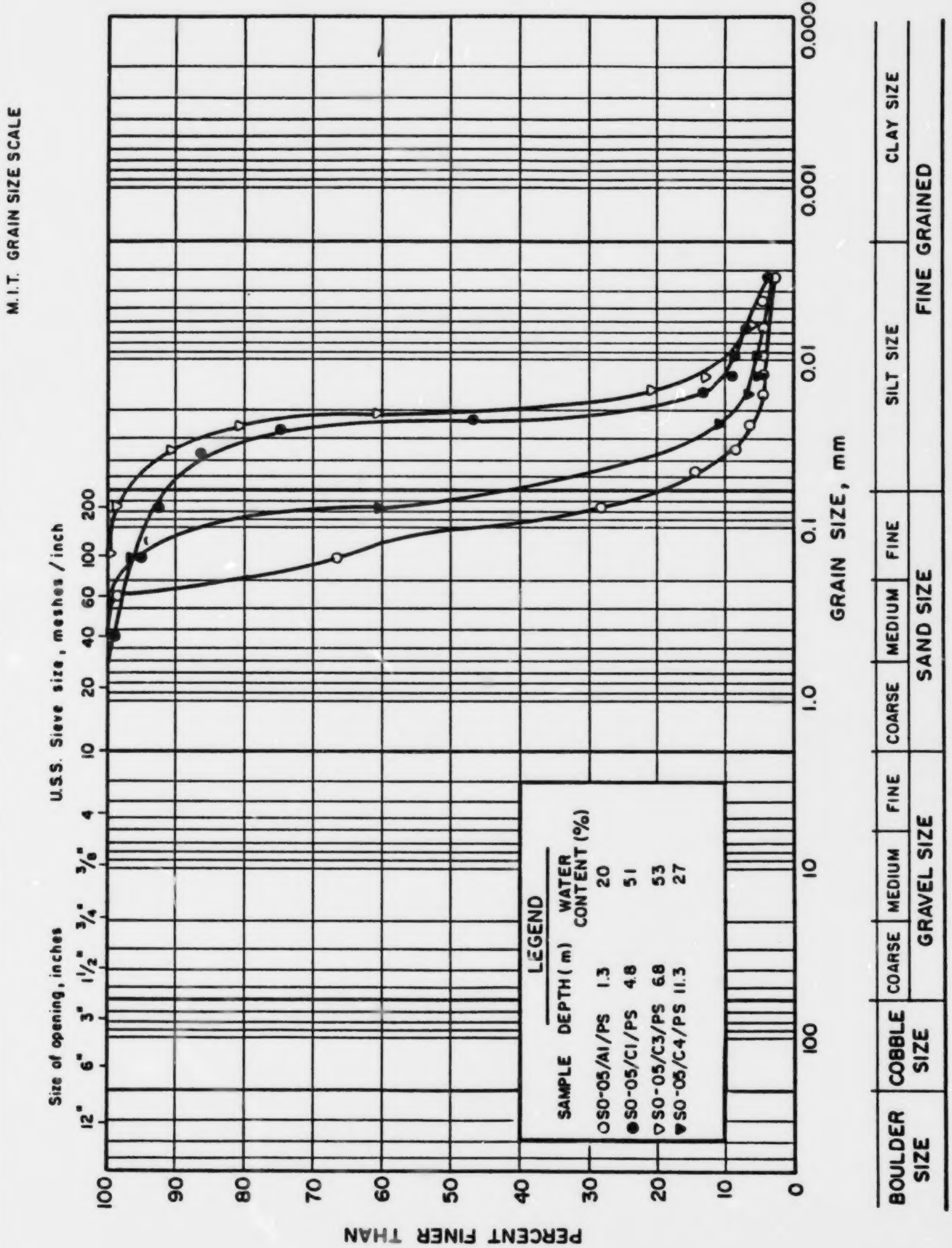
Form G.A. - D-6 (m)

Golder Associates

PROJECT No. 84I-134L

GRAIN SIZE DISTRIBUTION
BOREHOLE SO-05 TAILINGS

FIGURE 1.8



Form G.A.-D-6 (m)

Golder Associates

The specific gravity of a sample from borehole SO-03 was measured twice and produced values of 2.59 and 2.60.

1.3.7 Chemical Results

The chemical composition of the tailings and sub-tailings solids was determined for selected samples collected during the borehole drilling program. The chemical analyses included:

i) major cations and metals (silver, aluminum, boron, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, potassium, magnesium, manganese, molybdenum, sodium, nickel, phosphorus, lead, silicon, strontium, thorium, titanium, vanadium, zinc, zirconium)

ii) general parameters (total carbon, organic carbon, carbonate, total sulphur, reduced sulphur, cation exchange capacity)

iii) radionuclides (uranium, thorium-228, thorium-230, thorium-232, lead-210, radium-226)

Major cations and metals and general parameters were determined on 25 selected samples; these samples included 17 samples of tailings and 8 samples of sub-tailings solids. Duplicate analyses were performed on 2 of the 25 samples. Fourteen of the above samples were analysed for radionuclides, 1 of which was a sub-tailings sample. The results of the chemical analyses of solids are presented in Table 1.3.

The analyses for the major cations and metals were conducted using three different extraction techniques. The first set of analyses was conducted on a water leach, the objective being to determine the quality of potential leachate from water percolation. The second set of analyses was conducted on a weak acid leach to simulate the low pH conditions commonly found in the tailings areas in Elliot Lake. The final analyses were conducted on a strong acid digestion of the samples and represented the total leachable

Table 1.3 - TAILINGS SOLIDS - RESULTS OF INORGANIC PARAMETER ANALYSES

SITE	BOREHOLE	SAMPLE #	TYPE$^{(1)}$	DEPTH (m)	TIP MATERIAL	LEACH TYPE	Ag ppm	Al ppm	B ppm	Ba ppm	Be ppm	Ca ppm	Cd ppm	Co ppm
SO-01	a	7	PS	6.10-6.86	T	WATER	<.05	100	.30	.12	.030	2970	.1	7.3
						ACID	<.05	398	.44	<.05	.052	3170	.2	10.1
						TOTAL	<.5	23800	N/T	N/T	.52	2660	<1	41
SO-01	a	10	J	7.92-8.23	ST	WATER	<.05	15.3	.17	.29	<.005	879	<.1	7.2
						ACID	<.05	4970	.40	.54	.128	1260	.3	12.7
						TOTAL	<.5	46500	N/T	N/T	.78	8760	<1	21
SO-02	d	1	SS	0.30-0.91	T	WATER	<.05	12.6	<.04	1.37	<.005	22.6	<.1	7.9
						ACID	<.05	140	.25	.12	.007	24.4	<.1	8.1
						TOTAL	<.5	24300	N/T	N/T	.52	285	<1	31
SO-02	d	2	SS	1.52-2.13	T	WATER	<.05	29.1	.06	.11	<.005	3050	.1	8.0
						ACID	<.05	105	.28	<.05	<.005	3050	.2	9.7
						TOTAL	<.5	24500	N/T	N/T	.50	2700	<1	45
SO-02 DUPLICATE	d	2	SS			WATER	<0.24	17	<0.24	4.1	<0.12	2200	0.18	1.32
						ACID	<0.29	21.9	<0.34	4.2	<.145	2200	0.255	1.57
						TOTAL	<2	21000	N/T	172	<2	2450	<2	21
SO-02	a	3	PS	3.20-3.96	T	WATER	<.05	55.4	.16	.08	<.005	4980	.1	14.7
						ACID	<.05	160	.32	<.05	.008	4820	.2	17.5
						TOTAL	<.5	24800	N/T	N/T	.52	4470	1	51
SO-02	a	6	PS	7.77-8.53	T	WATER	<.05	108	.26	.09	.014	2840	.1	12.1
						ACID	<.05	673	.70	<.05	.036	2900	.2	15.0
						TOTAL	<.5	25500	N/T	N/T	.54	2790	1	50
SO-02	a	8	PS	10.82-11.58	T	WATER	<.05	52.5	.19	.16	.013	2180	.1	5.4
						ACID	<.05	352	.45	<.05	.027	2150	.2	6.5
						TOTAL	<.5	24700	N/T	N/T	.52	2270	<1	41
SO-04	b	1	SS1	0.91-1.52	T	WATER	<.05	83.1	.28	.27	.011	3160	.3	9.1
						ACID	<.05	163	.44	<.05	.011	3220	.2	11.7
						TOTAL	<.5	23400	N/T	N/T	.49	2860	1	59
SO-04	b	1	SS2	0.91-1.52	T	WATER	<.05	408	2.13	.07	.082	6070	.3	16.5
						ACID	<.05	3330	4.95	<.05	.312	6090	.3	31.3
						TOTAL	<.5	53300	N/T	N/T	1.38	27800	2	74
SO-04	b	2	SS	2.74-3.35	T	WATER	<.05	<.1	.60	.16	.005	6360	.2	8.3
						ACID	<.05	743	.96	.60	.060	6380	.3	15.4
						TOTAL	<.5	24700	N/T	N/T	.56	7840	1	56

Note

PS - Plastic Shelby
J - Jar
SS - Steel Shelby

TER ANALYSES

Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe ppm	K ppm	Mg ppm	Mn ppm	Mo ppm	Na ppm	Ni ppm	P ppm	Pb ppm	Si ppm	Sr ppm	Th ppm	Ti ppm	V ppm	Zn ppm	Zr ppm
.1	7.3	.2	1.31	84.2	40	47.0	3.6	<.5	10	4.4	<5	19.0	85.6	1.51	3.7	2.56	.24	4.7	8.9
.2	10.1	1.9	3.85	1880	120	74.0	4.4	<.5	10	5.7	33	32.5	364	1.59	38.3	46.2	1.34	5.6	16.6
<1	41	10	45.7	31700	18700	660	17	<5	1500	25	110	145	N/T	18.7	60	688	17.6	27	73
<.1	7.2	<.1	.11	18.7	90	47.2	5.5	<.5	20	.8	<5	<.5	85.3	1.03	1.1	<.05	<.05	.5	<.5
.3	12.7	8.2	9.98	4710	190	781	19.3	<.5	30	7.5	99	17.5	1830	1.77	10.6	127	6.85	7.6	3.6
<1	21	65	22.9	25300	17000	8440	199	<5	14900	35	210	30	N/T	83.0	17	1830	52.4	44	89
<.1	7.9	<.1	.14	53.3	90	4.3	.3	<.5	10	<.5	<5	70.0	60.3	.90	1.5	<.05	.12	<.5	<.5
<.1	8.1	.2	.65	141	120	8.3	.4	<.5	<10	<.5	<5	24.0	223	.50	1.6	3.38	.21	<.5	1.1
<1	31	9	32.4	26800	20000	660	11	<5	1700	14	90	165	N/T	17.6	26	664	16.5	21	45
.1	8.0	.1	8.02	232	20	7.4	.7	<.5	<10	3.2	<5	20.5	80.1	2.14	<.5	.11	.12	.6	<.5
.2	9.7	.4	10.2	699	80	11.9	.9	<.5	<10	3.6	37	27.0	238	1.75	25.4	58.1	.56	.5	4.1
<1	45	9	60.5	32000	18600	626	13	<5	1600	22	120	150	N/T	17.9	57	803	16.3	24	64
0.18	1.32	0.24	6.5	248	47	7.0	0.84	0.72	29	1.92	0.24	58	228	2.4	N/T	1.2	0.24	0.24	0.96
.255	1.57	0.39	9.15	508	52.2	7.2	<0.89	0.82	30.5	2.42	13.24	74	363	2.45	N/T	27.2	0.265	0.34	4.36
<2	21	9	36	25000	17400	440	125	<2	85	19	58	91	670000	19	N/T	960	26	21	87
.1	14.7	.3	3.80	42.8	20	15.7	1.1	<.5	<10	5.2	<5	6.0	90.0	2.41	.9	.19	.27	.9	<.5
.2	17.5	1.0	5.69	1040	130	29.9	1.5	<.5	<10	6.3	68	33.5	254	2.24	60.7	89.4	1.11	1.0	5.4
1	51	11	40.7	30200	18900	691	15	<5	1600	24	160	160	N/T	20.1	91	882	17.5	22	69
.1	12.1	.1	.61	63.4	70	12.7	.4	<.5	<10	4.5	<5	25.0	79.9	1.31	1.0	.11	.19	.7	.7
.2	15.0	1.7	2.74	1070	140	30.6	.9	<.5	<10	5.6	32	30.0	426	1.48	34.2	41.7	1.37	1.4	6.0
1	50	12	49.8	32300	20000	748	15	<5	1800	26	130	145	N/T	19.7	66	818	19.8	22	63
.1	5.4	.2	.69	48.3	70	38.8	1.3	<.5	10	3.2	<5	20.0	80.7	1.08	2.1	.47	.26	1.3	1.9
.2	6.5	1.5	2.30	1340	120	57.0	2.0	<.5	<10	3.7	26	30.0	324	1.19	28.5	33.5	1.08	2.0	6.1
<1	41	10	43.9	31400	20300	766	16	<5	2000	24	110	115	N/T	19.6	51	698	17.3	22	72
.3	9.1	.6	1.40	607	30	47.4	1.5	<.5	20	2.0	<5	21.5	52.0	2.03	2.9	.51	.29	1.1	.8
.2	11.7	.8	2.72	1170	110	64.5	1.8	<.5	20	2.0	48	29.0	184	1.86	65.9	85.6	1.25	.9	8.7
1	59	9	53.9	52400	18100	668	15	<5	1300	29	160	160	N/T	18.6	109	805	18.3	24	71
.3	16.5	.6	4.90	216	50	125	4.2	<.5	60	22.1	7	25.5	201	3.81	2.7	1.20	.66	4.1	3.1
.3	31.3	15.8	29.0	4670	220	194	5.6	<.5	60	34.5	204	40.0	1110	5.97	352	317	7.87	8.1	25.4
2	74	43	87.1	39800	32000	1770	29	<5	2200	60	370	550	N/T	34.8	383	1820	49.3	36	90
.2	8.3	.3	.68	6.2	160	182	11.2	<.5	70	3.5	6	5.5	161	2.90	<.5	.60	.34	3.4	2.6
.3	15.4	3.6	7.51	2520	270	249	13.6	<.5	60	8.2	69	32.0	884	3.07	83.1	81.4	2.03	8.0	14.1
1	56	14	52.8	33600	18900	947	28	<5	1700	31	180	195	N/T	21.4	123	943	17.9	30	79

Table 1.3 - **TAILINGS SOLIDS - RESULTS OF INORGANIC PARAMETER ANALYSES** /Page Two

SITE	BOREHOLE	SAMPLE #	TYPE$^{(1)}$	DEPTH (m)	TIP MATERIAL	LEACH TYPE	Ag ppm	Al ppm	B ppm	Ba ppm	Be ppm	Ca ppm	Cd ppm	Co ppm
SO-04	b	3	SS	4.27-4.88	T	WATER	<.05	<.1	1.23	.16	<.005	6340	.3	8.
						ACID	<.05	1730	2.43	<.05	.140	6250	.3	29.7
						TOTAL	<.5	46400	N/T	N/T	1.13	22100	2	66
SO-04	a	7	SS	7.32-7.92	T	WATER	<.05	<.1	.69	<.05	<.005	6340	.1	1.2
						ACID	<.05	1300	2.02	<.05	.097	6130	.3	18.
						TOTAL	<.5	46400	N/T	N/T	1.04	21900	2	45
SO-04 DUPLICATE	a	7	SS			WATER	0.58	43	<0.58	2.9	0.29	24200	0.58	2.9
						ACID	0.73	743	<1.38	3.0	0.39	24250	1.03	6.2
						TOTAL	<2	46000	N/T	290	<2	24500	<2	[illegible]
SO-04	a	11	J	9.91-10.06	ST	WATER	<.05	25.8	.85	.28	<.005	1460	<.1	85.5
						ACID	<.05	8640	.39	.52	.238	1890	<.1	174
						TOTAL	<.5	63400	N/T	N/T	.99	12200	<1	176
SO-04	a	12	J	10.36-10.97	ST	WATER	<.05	4.2	.07	.60	.005	308	<.1	6.7
						ACID	<.05	2580	<.04	.50	.173	876	.2	14.1
						TOTAL	<.5	63600	N/T	N/T	1.06	13000	<1	16
SO-05	a	1	PS1	0.91-1.68	T	WATER	<.05	53.4	<.04	.65	.009	132	.1	15.2
						ACID	<.05	165	.24	.13	.010	129	.1	15.3
						TOTAL	<.5	20200	N/T	N/T	.46	448	<1	40
SO-05	a	1	PS2	0.91-1.68	T	WATER	<.05	34.7	.06	.78	.010	132	<.1	17.1
						ACID	<.05	307	.47	.07	.018	129	<.1	18.8
						TOTAL	<.5	30700	N/T	N/T	.73	449	<1	57
SO-05	a	1	PS3	0.91-1.68	T	WATER	<.05	32.1	.08	.26	.011	1890	.2	12.9
						ACID	<.05	207	.48	.05	.014	1980	.2	14.1
						TOTAL	<.5	28900	N/T	N/T	.67	1980	<1	49
SO-05	g	1	PS	42.7-5.33	T	WATER	<.05	4.7	.74	.10	.008	5930	.3	7.9
						ACID	<.05	1900	<.04	<.05	.154	6160	.2	23.0
						TOTAL	<.5	57000	N/T	N/T	1.31	36400	2	53
SO-05	g	3	PS	6.40-7.16	T	WATER	<.05	12.1	.87	.07	.010	5690	.3	7.9
						ACID	<.05	1540	<.04	<.05	.124	6340	<.1	19.1
						TOTAL	<.5	53300	N/T	N/T	1.20	29900	2	49
SO-05	g	4	PS	10.97-11.73	T	WATER	<.05	36.4	.59	.16	.015	6300	.3	7.9
						ACID	<.05	857	.47	<.05	.054	6270	.3	11.1
						TOTAL	<.5	32400	N/T	N/T	.68	15100	2	40

Notes

PS - Plastic Shelby
J - Jar
SS - Steel Shelby

Ca ppm	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe ppm	K ppm	Mg ppm	Mn ppm	Mo ppm	Na ppm	NI ppm	P ppm	Pb ppm	SI ppm	Sr ppm	Th ppm	Ti ppm	V ppm	Zn ppm	Zr ppm
340	.3	8.8	.2	.46	3.3	200	240	21.9	<.5	100	5.0	6	2.0	183	4.31	<.5	.36	.45	1.7	1.8
250	.3	29.7	12.4	24.4	7600	320	314	29.4	<.5	100	19.1	161	36.5	1350	4.46	274	224	5.32	9.6	26.6
100	2	66	33	71.4	39000	29200	1570	48	<5	2400	41	320	450	N/T	25.8	311	1580	41.2	43	89
340	.1	1.2	.1	.12	.9	120	273	11.0	<.5	60	2.2	5	<.5	119	4.89	<.5	<.05	.17	.5	<.5
130	.3	18.4	8.2	16.1	6000	200	363	19.3	<.5	60	15.4	126	36.5	1040	4.99	213	196	4.52	9.6	22.9
900	2	45	31	64.0	30400	29800	1590	38	<5	2000	34	260	370	N/T	29.7	239	1500	43.3	36	84
200	0.58	2.9	1.73	0.29	6.9	138	360	16.7	4.6	350	5.2	2.3	15.6	340	12.7	N/T	10.4	0.36	1.73	4.6
250	1.03	6.2	5.83	14.79	1857	160	386	18.9	5.00	371	11.0	4.5	53.6	1130	13.3	N/T	49.4	2.16	8.03	6.7
500	<2	30	48	68	32800	28000	1800	45	7	950	20	110	350	580000	28	N/T	1900	64	30	124
460	<.1	85.5	.1	.08	159	120	138	15.4	<.5	50	23.1	<5	<.5	125	1.70	1.3	<.05	<.05	1.4	<.5
890	<.1	174	19.0	8.17	7200	280	507	24.2	<.5	60	53.9	40	17.0	2150	2.52	20.5	117	17.3	8.1	11.8
200	<1	176	94	19.5	27400	18700	9780	283	<5	19300	82	220	25	N/T	163	27	2820	68.2	50	147
308	<.1	6.7	<.1	.10	7.8	80	66.1	5.5	<.5	40	.5	<5	<.5	88.9	.71	1.2	<.05	.18	<.5	<.5
876	.2	14.1	10.1	16.1	4030	240	1040	26.1	<.5	60	6.0	108	4.0	1350	1.85	10.3	100	14.2	9.8	4.1
000	<1	18	65	37.4	25100	22600	8430	286	<5	24000	34	300	10	N/T	221	14	3030	72.5	51	150
132	.1	15.2	.2	.64	136	80	95.4	1.8	<.5	20	1.1	<5	20.0	46.7	.25	2.4	.09	.36	3.7	<.5
29	.1	15.3	.3	1.12	368	130	104	1.9	<.5	20	1.1	6	23.0	194	.32	3.3	7.39	.43	3.7	2.1
448	<1	40	9	42.9	24700	17800	655	12	<5	1700	14	100	75	N/T	17.1	39	731	13.7	23	62
132	<.1	17.1	.2	.20	62.2	150	60.9	1.3	<.5	20	1.0	<5	37.5	84.3	.68	2.0	.09	.33	<.5	<.5
129	<.1	18.8	.5	1.95	713	240	87.4	1.7	<.5	20	1.0	19	37.0	336	.45	5.1	31.6	.60	<.5	5.7
49	<1	57	16	48.3	37400	22900	1020	19	<5	1900	23	140	250	N/T	17.7	44	1140	23.9	28	76
90	.2	12.9	.2	.64	75.9	90	57.2	1.4	<.5	20	1.8	<5	25.0	80.5	1.01	1.8	.12	.39	<.5	<.5
80	.2	14.1	.5	2.40	430	150	90.6	1.9	<.5	10	2.0	19	27.0	332	1.07	7.6	43.2	.64	<.5	6.5
80	<1	49	14	43.0	32700	21600	933	16	<5	1700	22	130	265	N/T	18.7	42	982	20.6	23	72
30	.3	7.9	.3	1.06	6.0	120	351	13.2	<.5	40	8.5	7	13.0	230	3.44	.7	.85	.60	3.2	3.9
60	.2	23.0	20.5	28.7	13200	160	503	18.8	<.5	20	26.1	209	45.0	1450	3.42	316	301	5.99	11.2	31.9
00	2	53	46	75.3	37500	33600	2070	44	<5	1800	47	370	600	N/T	29.9	389	1860	53.7	36	91
90	.3	7.9	.4	1.35	6.7	130	168	7.4	<.5	50	8.0	8	19.0	204	3.97	2.4	.98	.73	4.8	4.5
40	<.1	19.1	10.3	22.6	11300	160	237	12.1	<.5	20	21.2	179	55.0	1220	4.19	261	236	4.78	10.7	28.7
00	2	49	39	73.6	35300	32500	1720	35	<5	1800	43	330	425	N/T	32.6	331	1690	48.7	38	90
00	.3	7.9	.4	1.14	24.3	70	242	7.7	<.5	30	5.0	7	13.5	173	3.10	1.7	.89	.74	3.8	3.4
270	.3	11.1	4.8	8.22	5330	120	345	10.7	<.5	<10	7.9	71	41.5	755	3.73	100	110	2.89	6.1	13.3
00	2	40	20	48.0	28500	23800	1280	28	<5	1800	25	180	200	N/T	26.1	117	1040	28.3	30	70

Table 1.3 - TAILINGS SOLIDS - RESULTS OF INORGANIC PARAMETER ANALYSES - Page Three

SITE	BOREHOLE	SAMPLE #	TYPE$^{(1)}$	DEPTH (m)	TIP MATERIAL	LEACH TYPE	Ag ppm	Al ppm	B ppm	Ba ppm	Be ppm	Ca ppm	Cd ppm	Co ppm
SO-05	g	5	PS	15.24-16.00	ST	WATER	<.05	4.0	.37	.38	<.005	116	<.1	.6
						ACID	<.05	3520	.17	.61	.345	3540	1.4	12.8
						TOTAL	<.5	25100	N/T	N/T	.68	6870	1	18
SO-05	b	10	J	15.85-16.00	ST	WATER	<.05	3.2	.06	.75	.010	157	.1	10.6
						ACID	<.05	1800	<.04	.82	.150	1060	.4	23.7
						TOTAL	<.5	59100	N/T	N/T	1.12	11400	1	26
SO-05	g	6	PS	16.00-16.76	ST	WATER	<.05	12.6	.10	.68	.014	130	<.1	5.5
						ACID	<.05	887	<.04	.50	.061	737	.2	7.1
						TOTAL	<.5	57300	N/T	N/T	1.03	10600	2	8
SO-05	b	11	J	16.00-16.92	ST	WATER	<.05	1.2	.21	.29	<.005	445	<.1	1.5
						ACID	<.05	2670	<.04	.56	.077	1520	.2	52.9
						TOTAL	<.5	52500	N/T	N/T	.88	11700	2	56
SO-05	b	12	J	19.66-20.27	ST	WATER	<.05	<.1	.18	.30	<.005	2330	.1	1.1
						ACID	<.05	1330	<.04	.27	.059	6010	.3	23.1
						TOTAL	<.5	55700	N/T	N/T	.97	16900	2	28

Note

1) PS - Plastic Shelby
J - Jar
SS - Steel Shelby

Ca ppm	Cd ppm	Co ppm	Cr ppm	Cu ppm	Fe ppm	K ppm	Mg ppm	Mn ppm	Mo ppm	Na ppm	Ni ppm	P ppm	Pb ppm	Si ppm	Sr ppm	Th ppm	Ti ppm	V ppm	Zn ppm	Zr ppm
116	<.1	.6	<.1	.18	3.0	20	33.1	2.2	<.5	30	<.5	<5	<.5	136	.33	1.1	.07	.32	<.5	<.5
3540	1.4	12.8	6.2	56.5	4980	40	671	65.4	<.5	50	15.2	57	<.5	1060	10.7	14.5	27.3	30.9	57.2	8.0
6870	1	18	39	84.9	10800	5500	2700	143	<5	7000	40	320	5	N/T	74.8	26	1330	46.9	96	69
157	.1	10.6	.1	.92	10.5	70	60.8	4.5	<.5	40	4.7	<5	<.5	72.8	.50	1.3	<.05	.18	6.0	<.5
1060	.4	23.7	5.4	25.7	3850	240	1280	32.4	<.5	60	16.8	225	3.0	1270	2.57	10.7	83.0	17.4	29.9	2.3
11400	1	26	32	30.3	13500	23700	5730	201	<5	23900	29	350	10	N/T	212	16	2040	50.5	62	124
130	<.1	5.5	<.1	2.19	74.0	40	74.0	5.5	<.5	30	3.1	<5	<.5	46.6	.43	.7	<.05	.11	2.5	<.5
737	.2	7.1	2.9	6.91	2270	100	681	19.6	<.5	40	6.0	178	1.5	827	1.75	5.6	57.8	5.69	8.2	1.7
10600	2	8	23	10.3	9550	22800	4130	162	<5	24600	16	280	5	N/T	204	13	1370	32.0	36	72
445	<.1	1.5	.2	<.08	.8	190	202	2.3	<.5	110	<.5	<5	<.5	70.6	.89	1.4	<.05	.26	<.5	<.5
1520	.2	52.9	8.1	4.97	5410	610	2190	42.4	<.5	240	8.2	200	5.0	1560	3.94	8.7	65.4	9.70	11.3	2.6
11700	2	56	55	24.5	20800	17700	9830	248	<5	20200	31	300	10	N/T	121	16	2060	53.1	45	92
2330	.1	1.1	.2	.10	1.1	90	119	.5	<.5	50	<.5	<5	<.5	34.0	1.64	1.1	<.05	.26	<.5	<.5
6010	.3	23.1	3.6	5.90	5420	270	1810	80.8	<.5	110	6.1	236	1.5	1090	5.52	3.9	46.8	4.72	8.1	5.5
16900	2	28	36	20.2	18800	21700	6550	273	<5	23100	22	360	5	N/T	195	14	1830	43.8	43	124

concentrations for the tailings solids.

Two samples, SO-04/B1/SS and SO-05/A1/PS were subdivided into two and three sub-samples respectively because each of the samples had distinct layering. These sub-samples were submitted separately to the laboratory for analysis. The results are presented for each sub-sample in Table 1.3.

A rigorous interpretation of the chemical composition of the tailings solids was beyond the general scope of this study. The chemical data did, however, indicate that the tailings solids in the Lacnor basin were similar to those in other tailings basins in the Elliot Lake area (Feenstra, et al., 1985; Dubrovsky, et al., 1985). Much of the tailings solids consisted of relatively insoluble aluminosilicate minerals; high concentrations of silicon, aluminum, sodium and potassium, the primary constituents of aluminosilicate minerals, were present in the total digestions of the solids samples.

Soluble sulphur, which likely occurred as sulphate minerals such as gypsum, was present in the tailings solids at concentrations of as much as 5 per cent. Water soluble calcium, which occurs with sulphate in gypsum, was present at concentrations of as much as several thousand ppm. Iron, often present in minerals soluble in the weak acid leach, also occurred at concentrations of as much as several thousand ppm in the tailings solids (see Table 1.4).

Reduced sulphur, indicative of pyrite and other sulphide minerals, was present in the tailings solids, but the measured concentrations of less than a few per cent were lower than those determined for other tailings basins in the Elliot Lake area (Feenstra, et al., 1985; Dubrovsky, et al., 1985.) Concentrations of carbonate minerals were also low and typically comprised less than 0.1 per cent of the tailings solids.

For most of the cations and metals, with the exception of calcium noted above, the highest observed concentrations occurred in the total digestions and decreased in the dilute acid and water leach extractions. This trend is expected because the solubilities of most minerals increase as the pH is

Table 1.4 - TAILINGS SOLIDS - RESULTS OF CARBON, CARBONATE, SULPHUR AND RADIONUCLIDE ANALYSES

SITE	BOREHOLE	SAMPLE #	SAMPLE TYPE(4)	DEPTH (m)	TIP MATERIAL	TOT.C. ($)	ORG.C ($)	CO3= ($)	CO3=(1) ($)	TOT.S ($)	S= ($)	CEC (meq/100g)	U (ppm)	Th228 (Bq/g)	Th230 (Bq/g)	Th232 (Bq/g)	Pb210 (Bq/g)	Ra226 (Bq/g)
SD-01	a	7	PS	6.10-6.86	T	<.02	<.02	<.1	<.025	3.26	.360	13.9	44.7 48(3)	0.20 0.18(3) (+-.08)	2.60 2.46(3) (+-.16)	0.20 0.16(3) (+-.08)	3.45 3.20(3) (+-.14)	3.35 3.88(3) (+-.17)
SD-01	a	10	J	7.92-8.23	ST	.44	.44	<.1	.07	.524	.240	5.7						
SD-02	d	1	SS	0.30-0.91	T	<.02	<.02	<.1	.05	2.64	.200	.6	10.3	0.08	2.70	0.07	3.10	3.75
SD-02	d	2	SS	1.52-2.13	T	<.02	<.02	<.1	.05	3.04	.040	12.9	34.5	0.27	3.10	0.24	4.40	5.15
SD-02 Duplicate	d	2	SS								1.65/1.45(2)	0.27						
SD-02	a	3	PS	3.20-3.96	T	<.02	<.02	<.1	<.025	3.30	.200	23.3	48.6	0.22	2.60	0.20	2.80	3.65
SD-02	a	6	PS	7.77-8.53	T	<.02	<.02	<.1	.15	3.06	.040	13.2	35.8	0.20	2.10	0.17	3.00	3.45
SD-02	a	8	PS	10.82-11.58	T	<.02	<.02	<.1	<.025	3.22	.280	9.7	37.8	0.20	2.40	0.23	3.30	3.15
SD-04	b	1	SS1	0.91-1.52	T	<.02	<.02	<.1	.07	4.32	.040	14.5	30.1	0.20	2.60	0.16	3.40	4.20
SD-04	b	1	SS2	0.91-1.52	T	.12	<.02	.6	.025	5.70	.260	97.3						
SD-04	b	2	SS	2.74-3.35	T	.10	.08	.1	.07	3.60	.160	42.7	58.4 62.3(3)	0.86 0.84(3) (+-.02)	8.50 11.8(3) (+-.3)	0.89 0.60(3) (+-.02)	8.70 6.60(3) (+-.2)	8.85 11.2(3) (+-.2)

Notes

1 Chemex Analysis
2 Beak Analysis
3 Monenco Analysis

4 - PS - Plastic Shelby
J - Jar
SS - Steel Shelby

Table 1.4 - TAILINGS SOLIDS - RESULTS OF CARBON, CARBONATE, SULPHUR AND RADIONUCLIDE ANALYSES - Page Two

SITE	BOREHOLE	SAMPLE #	SAMPLE TYPE[4]	DEPTH (m)	TIP MATERIAL	TOT.C. (%)	ORG.C (%)	CO3= (%)	CO3=[1] (%)	TOT.S (%)	S= (%)	CEC (meq/100g)	U (ppm)	Th228 (Bq/g)	Th230 (Bq/g)	Th232 (Bq/g)	Pb210 (Bq/g)	Ra226 (Bq/g)
SD-04	b	3	SS	4.27-4.88	T	.16	.02	.7	.025	4.18	.600	67.8	65.9	0.96	9.00	0.91	9.40	9.30
SD-04	a	7	SS	7.32-7.92	T	.14	<.02	.7	.095	3.60	.340	67.6						
SD-04 DUPLICATE	a	7	SS								1.87/2.14[2]	2.7/3.1						
SD-04	a	11	J	9.91-10.06	ST	1.72	1.70	.1	.025	.430	.385	12.1						
SD-04	a	12	J	10.36-10.97	ST	.24	.24	<.1	.045	.060	.052	4.3						
SD-05	a	1	PS1	0.91-1.68	T	.14	.10	.2	.095	2.54	.140	2.4						
SD-05	a	1	PS2	0.91-1.68	T	.40	.30	.5	.095	3.50	.060	2.2	24.6	0.15	7.50	0.11	7.90	8.20
SD-05	a	1	PS3	0.91-1.68	T	.34	.32	.1	.025	3.22	.220	9.3						
SD-05	g	1	PS	42.7-5.33	T	.76	.74	.1	.07	4.20	.300	65.0	79.1	1.37	12.50	1.30	12.70	12.70
SD-05	g	3	PS	6.40-7.16	T	.22	.20	.1	.07	3.70	.800	62.9	69.9	1.24	9.50	1.30	11.20	11.30
SD-05	g	4	PS	10.97-11.73	T	.52	.40	.6	.055	3.44	.200	59.3	50.2	0.42	6.00	0.44	6.10	5.90

Notes

1 Chemex Analysis	4 - PS - Plastic Shelby
2 Beak Analysis	J - Jar
3 Monenco Analysis	SS - Steel Shelby

Table 1.4 - TAILINGS SOLIDS - RESULTS OF CARBON, CARBONATE, SULPHUR AND RADIONUCLIDE ANALYSES - Page Three

SITE	BOREHOLE	SAMPLE #	TYPE(4)	DEPTH (m)	TIP MATERIAL	TOT.C. (%)	ORG.C (%)	CO3= (%)	CO3=(1) (%)	TOT.S (%)	S= (%)	CEC (meq/100g)	U (ppm)	Th228 (Bq/g)	Th230 (Bq/g)	Th232 (Bq/g)	Pb210 (Bq/g)	Ra226 (Bq/g)
SO-05	g	5	PS	15.24-16.00	ST	20.2	19.3	4.5	<.025	.403	.033	12.9	10.2	0.08	0.60	0.07	0.60	0.60
SO-05	b	10	J	15.85-16.00	ST	.55	.60	<.1	<.025	.042	.042	3.1						
SO-05	g	6	PS	16.00-16.76	ST	<.02	<.02	<.1	<.025	.046	.006	2.1						
SO-05	b	11	J	16.00-16.92	ST	<.02	<.02	<.1	<.025	.240	.240	7.3						
SO-05	b	12	J	19.66-20.27	ST	.22	.12	.5	1.07	.206	.160	21.0						

Notes

1 Chemex Analysis
2 Beak Analysis
3 Monenco Analysis

4 - PS - Plastic Shelby
J - Jar
SS - Steel Shelby

lowered from neutral conditions.

There were no readily observable trends in the radiological data for the tailings solids. Concentrations of uranium ranged from approximately 10 to 80 ppm. Concentration ranges for the other radiological parameters in the tailings solids are listed below:

- Radium-226: 0.60 to 12.7 Bq/g
- Thorium-228: 0.08 to 1.37 Bq/g
- Thorium-230: 0.60 to 12.50 Bq/g
- Thorium-232: 0.07 to 1.3 Bq/g
- Lead-210: 0.60 to 12.7 Bq/g

Although not included in the original proposal, two tailings samples were collected for rare earth element scans. Sample SS-01 was collected from a coarse tailings area just east of SO-01. Sample SS-05 was a sample collected from an area of mixed coarse and fine tailings just west of SO-05. The samples were obtained from hand-dug test pits at each location. The samples were vertically integrated composites of tailings materials from depths of 0.3 to 0.8 m below ground surface. The samples were stored in plastic bags and transported back to Golder Associates' Mississauga office. Sample analysis was performed by X-ray Assay Laboratories Ltd. of Don Mills, Ontario using direct coupled plasma (DCP) and neutron activation (NA) methods.

The results of the rare earth element scans are presented in Table 1.5. The concentrations of rare earth elements in each sample were similar.

1.3.8 Quality Assurance/Quality Control (QA/QC)

The sampling methodologies and the precautions taken to preserve the chemical

Table 1.5 - TAILINGS SOLIDS - RARE EARTH ELEMENT SCAN

ELEMENT	METHOD(1)	DETECTION LIMIT (PPM)	SS-01(2) (ppm)	SS-05(3) (ppm)
YTTRIUM	DCP	1.000	6	6
LANTHANUM	NA	0.100	189	200
CERIUM	NA	1.000	309	341
PRASEODYMIUM	DCP	2.000	31	36
NEODYMIUM	NA	3.000	104	98
SAMARIUM	NA	0.010	13.5	14.5
EUROPIUM	NA	0.050	0.59	0.64
GADOLINIUM	DCP	2.000	5	5
TERBIUM	NA	0.100	0.4	0.8
HOLMIUM	DCP	0.500	<0.5	<0.5
ERBIUM	DCP	0.500	<0.5	<0.5
THULIUM	DCP	0.500	<0.5	<0.5
YTTERBIUM	NA	0.050	0.64	0.58
LUTETIUM	NA	0.010	0.09	0.07

Notes

(1) DCP: Direct Current Plasm
NA: Neutron Activation
(2) Site just east of SO-01
(3) Site just west of SO-05

integrity of the tailings and sub-tailings solids samples during the field collection process were described previously in Section 1.3.4. With the exception of the samples obtained for the analysis of the rare earth elements, all solids samples were collected using the drilling and associated soil sampling equipment. The two samples for the determination of rare earth elements were obtained from hand-dug test pits.

The samples of solids for chemical analysis were subdivided into separate portions prior to their submission to the appropriate analytical laboratories. Separate portions were required for the analyses of radionuclides, inorganic and general parameters, and the duplicate analyses for selected samples. The samples from the field were split by Golder Associates personnel at the Barringer laboratory.

The tailings solids samples for chemical analyses were obtained in the field in either steel or plastic Shelby Tubes. The first step in the sample splitting process was the removal of the wax seal from the end of the Shelby tube and the extrusion of the core onto a clean plastic sheet. The surficial coating of the core had been subjected to some disturbance during transport and extrusion and this was scraped from the core. The inner part of the core was then separated longitudinally into portions for the primary and duplicate, if necessary, analyses of general parameters and radionuclides. This sample splitting technique provided tailings material from the same stratigraphic depths and of similar grain-size characteristics to each laboratory for chemical testing. The knives and spoons for core splitting were cleaned thoroughly and new sheets of plastic were used for each individual core.

With the exception of two sub-tailings samples obtained in plastic Shelby tubes and handled in the manner described above, the sub-tailings samples for chemical analysis were collected in glass jars during the drilling program. The sub-tailings samples were generally only several hundreds of grams; equal portions were separated for general and radionuclide analyses. No duplicate analyses of sub-tailings materials were performed.

It should be noted that the solids samples were not dried prior to splitting because carbonate was included in the analytical program. This precaution was necessary because the porewater in the samples contained potentially high concentrations of ferrous iron. The oxidation of ferrous to ferric iron, a process which is accelerated upon exposure of the sample to air during drying, could result in the generation of acidic conditions in the sample which could also cause a depletion of the carbonate material within the samples.

As part of the quality assurance protocols for the determination of the chemical composition of the tailings solids, duplicate samples of 2 of the 25 samples analysed by the primary laboratories were submitted to check laboratories for chemical analyses. Duplicates of samples SO-02-02/55 and SO-04/A7/55 were submitted for check analyses of major cation, metal and general chemical parameters and, for the radiological parameters, duplicates of samples SO-01/A7/P3 and SO-04/B2/55 were used for check analyses.

For this component of the study the primary and check laboratories for the analyses of major cation, metal and general chemical parameters were Barringer Magenta Limited of Rexdale, Ontario and Beak Analytical Services of Mississauga, Ontario respectively. The primary and check laboratories for the radiological parameters were Chemex Labs Limited of Vancouver, British Columbia and Monenco Analytical Laboratories of Calgary, Alberta respectively. A full discussion of the analytical methods used by the above laboratories is included in Appendix 5. The discussion on the laboratories also summarizes the analytical quality control protocols practised for this study.
Although there was some general agreement, discrepancies existed between the data received from the primary and check laboratories for the analyses of major cations, metals and general parameters. Variability between the results from the primary and check laboratories for the analyses of radiological parameters was generally low. The variability in the data could have resulted from sample splitting procedures and/or analytical causes.

As noted above, the primary and duplicate solids samples were obtained from the same cores. Because of the effort to maintain the integrity of the samples for the carbonate analyses, the samples were not dried or homogenized prior to the splitting procedure. While there is inherent variability in the concentrations of chemical parameters in adjacent sections of the same core, it is not expected that the variability would be large in laterally adjacent positions of the same stratigraphic layer in a core of tailings of several centimetres in diameter. The sub-samples submitted to each laboratory generally exceeded the volumes of material required for the desired analyses. Thus, each laboratory was responsible for sample homogenization and splitting prior to the analyses. Any differences in techniques that resulted in differences in the grain size fractions of the materials to be analysed in the primary and check laboratories could also have contributed to the resultant variability of the chemical data.

Another potential cause of variability in chemical results was the use of different analytical methods. For example, detection limits and sensitivity to interferences may vary between techniques. The analytical methods, protocols and quality control measures used by the primary and check laboratories are summarized in Appendix 5. For some parameters, different analytical methods were used by the primary and check laboratories.

For the major cations and metals analyses, Barringer Magenta and Beak used different leaching and digestion techniques on the tailings solids samples. Barringer Magenta employed demineralized water, dilute sulphuric acid and a mixture of hydrofluoric, perchloric and nitric acid for the water leach, weak acid leach and total digestion of separate portions of the solids samples respectively. Beak used demineralized water, dilute nitric acid, and lithium dibromide dissolved in nitric acid for the leach extractions and digestion; however, the dilute acid leach extraction and digestion were performed on the residue remaining from the water and dilute acid extractions respectively. Thus, analytical results, especially for water or dilute-acid soluble parameters, could be expected to differ between the primary and duplicate samples.

In addition to the differences in leach extraction and digestion methods, Barringer Magenta used an Inductively Coupled Argon Plasma (ICAP) scan for the analyses of major cations and metals whereas Beak used a Direct Coupled Plasma (DCP) emission scan. Each of the above methods are generally accepted and used routinely in analytical laboratories but they provide slightly different detection limits and sensitivity for particular metals or cations. The variability of the results provided by the two methods is generally greatest when concentrations of the various parameters are low and in the order of their respective detection limits.

There were also discrepancies between the results provided for the primary and duplicate analyses of cation exchange capacity and reduced sulphur. The cation exchange capacity values determined by Beak for the duplicate samples were between 1 and 2 orders of magnitude less than those measured by Barringer Magenta. The values determined by Beak and Barringer Magenta respectively for sample SO-02-D2-SS were 0.27 and 12.9 meq/100g and for sample SO-04-A7-SS were 2.7 and 67.6 meq/100g. Cation exchange capacity values were reported to range from 2.9 to 15.7 meq/100g with a mean value of 2.9 meq/100g in another tailings basin in the Elliot Lake area (Feenstra, et al., 1985). These low cation exchange values were a consequence of the generally low concentrations of clay minerals in the tailings solids. Assuming that the mineralogical compositions of the tailings basins in the Elliot Lake area are similar, generally low cation exchange capacity values would also be expected in the Lacnor basin. Thus, based on previous work in the Elliot Lake area, values of cation exchange capacity in excess of 30 to 40 meq/100g as reported by Barringer Magenta are questionable.

There were also discrepancies between the values of reduced sulphur reported by Beak and Barringer Magenta. The reduced sulphur concentrations reported by Beak for samples SO-02-D2-SS and SO-04-A7-SS were 1.65 and 1.87 per cent respectively while Barringer Magenta reported values of 0.04 and 0.34 per cent for the same samples. If it is assumed that all of the reduced sulphur present in the tailings solids was pyrite, then the Beak and Barringer Magenta analyses indicated that the pyrite content was of the order of 3 and less than 0.6 per cent of the tailings solids in the above samples. The maximum pyrite content reported by Barringer Magenta for all analyses performed during the study of the Lacnor basin was 1.5 per cent. Previous investigations of other tailings basins in the Elliot Lake area have indicated that the pyrite content of tailings solids ranged from less than 2 to approximately 10 per cent (Feenstra, et al., 1985, Dubrovsky, et al., 1985).

Carbonate content in the tailings solids was very low and typically was of the order of fractions of a per cent by weight. The analysis of carbonate in the tailings solids proved to be a problem to Barringer Magenta. They attempted to dissolve the carbonate in a tailings sample with dilute hydrochloric acid and back-titrate with a sodium hydroxide solution to calculate the volume of acid consumed during the reaction between the carbonate in the sample and the dilute acid. Because of the inherent acid generating potential and generally low concentrations of carbonate in the tailings solids, the back-titration for several of the analyses indicated there had been an apparent net increase in the volume of acid added to the sample rather than the depletion of acid that would be expected if carbonate was present. In an effort to reduce the acid generating potential of the solids samples, Barringer Magenta rinsed the portions of samples for carbonate analyses with methanol to remove the porewater which contained high concentrations of ferrous iron from the sample; however, the acid generating potential of the solids, possibly due to the presence of sulphide minerals, remained high. The limit of detection of the carbonate analyses by Barringer Magenta was quoted to be 0.1 per cent.

When it became apparent that there were problems with the carbonate analyses, methanol-rinsed samples were obtained from Barringer Magenta and were shipped to Chemex. Chemex performed carbonate analyses of the solids using a Leco furnace; carbon as carbonate was assumed to be the difference between the total carbon in a portion of the sample and the organic carbon in a second portion of the sample that had been acid leached to remove carbonate. Their quoted limit of detection was 0.025 per cent and in all but two of the twenty-five samples analysed, the carbonate concentrations were less than 0.1 per cent.

There was relatively good agreement between the analytical results obtained from the primary and check laboratories, Chemex and Monenco respectively, for the radiological parameters in tailings solids. One reason for this agreement was that both laboratories used similar analytical procedures. Further details of the analytical procedures and quality control protocols practised by the laboratories are provided in Appendix 5.

1.4 Off-Tailings Rock

A total of nine separate boreholes were drilled at two sites south of the basin in the valleys in the vicinity of the surface water monitoring locations SW-01 and SW-02 (see Figure 1.1 and the Record of Boreholes that follows this appendix). Based on the geological mapping of the basin and previous experience in the Elliot Lake area, these valleys were considered to contain the major potential fault or fracture zones, and hence the major groundwater seepage pathways exiting from the tailings area.

Three boreholes were put down at SO-06 and six were advanced at SO-07. The 76 cm diameter boreholes were collared on bedrock and advanced to depths between 3.4 and 31.15 m at angles between 55 and 68 degrees. The boreholes were oriented to intersect what are considered to be the major geological features within each valley at varying depths.

No solid samples were collected during these operations since all holes were drilled pneumatically. The cuttings were, however, examined to determine the rock types encountered. The details of each boring are summarized in the Record of Boreholes following this appendix.

At SO-06, there was a change in colour of the cuttings at depths between 29.9 to 30.3 m in Borehole SO-06a and at 15.2 m in Borehole SO-06b. The location of these colour changes coincides closely with an extrapolation to depth of the near vertical cliff adjacent to surface water monitoring location SW-01.

At SO-07, the frequent change in rock type, water bearing seams encountered in the boreholes and the surface bedrock exposures indicate that northwest-southwest trending near vertical diabase dykes and shear zones strike through the valley at surface water monitoring location SW-02. A plan of the borehole locations and a cross-section through this area are shown on Figure 1.9.

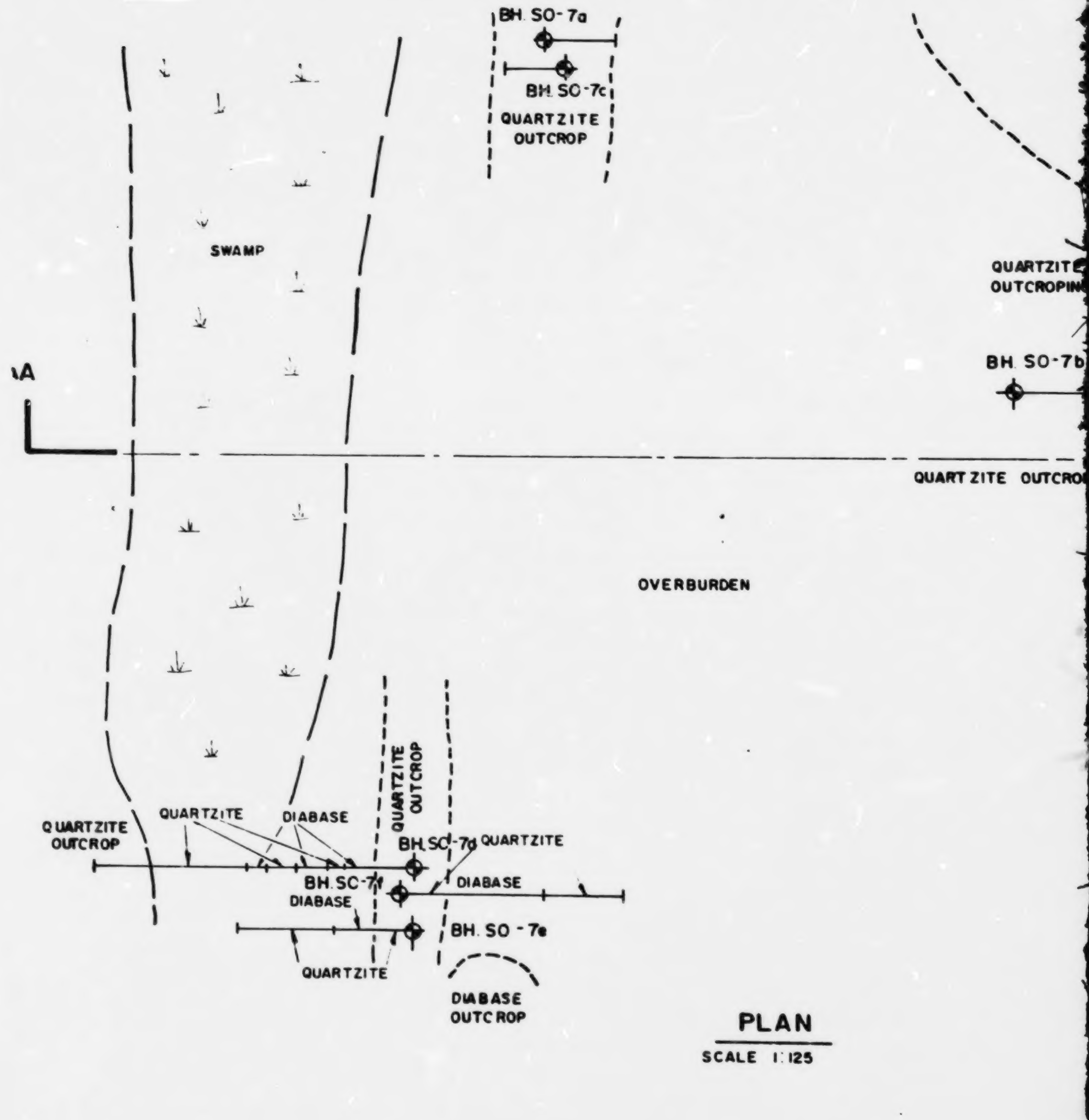
1.5 Porewater/Groundwater

1.5.1 Piezometer Installation

Piezometers installed in the tailings or underlying subsoils were of similar construction to those used in previous porewater investigation of uranium tailings areas in the Elliot Lake area (Dubrovsky, et al., 1985, Feenstra et al, 1985). They consisted of a large diameter solid PVC plastic drive point connected to 3.18 cm I.D. threaded Schedule 80 PVC pipe by a 15 cm length of perforated PVC pipe. The intake screen consisted of a 15 cm section of porous polyethylene (Vyon) fitted over the perforated PVC and sealed on the edges with Silicon sealant. The perforated PVC provided an effective screen length of 12.7 cm.

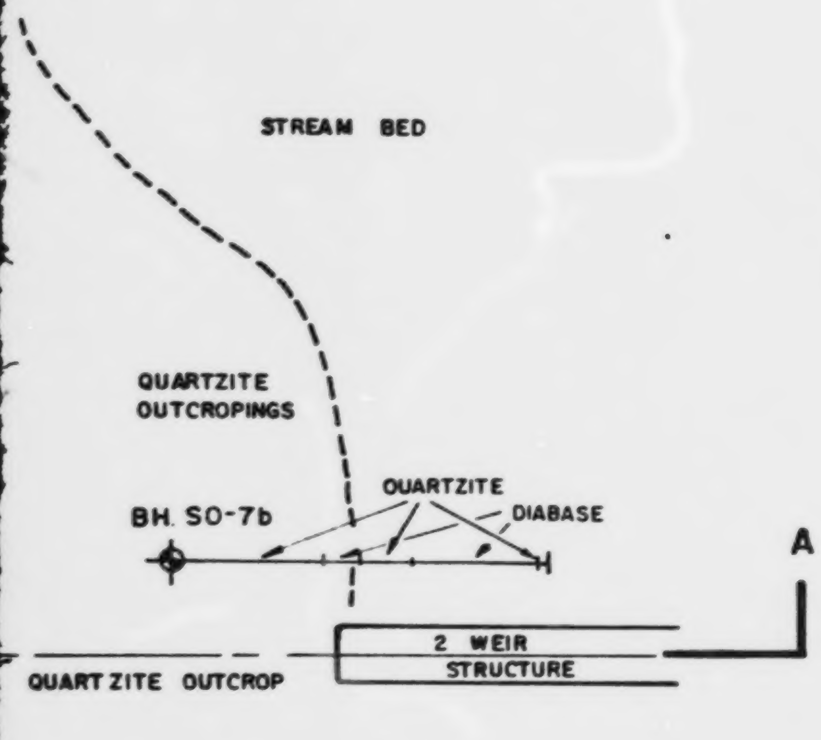
The piezometers were installed in individual holes in the tailings by using hollow stem augers to advance the borehole to just above the desired depth The piezometers were inserted through the hollow stem auger and pushed approximately 0.3 m into the relatively undisturbed material below. Subsequently, the augers were retracted from the borehole, and the boreholes caved in to within a metre or two of ground surface. This upper section of the borehole was backfilled with auger cuttings. No seals of any kind were used in installations augered only in the tailings, as it has been demonstrated from past experience that the saturated tailings collapse back tightly around the piezometer pipe and inhibit vertical movement of porewater within the borehole annulus.

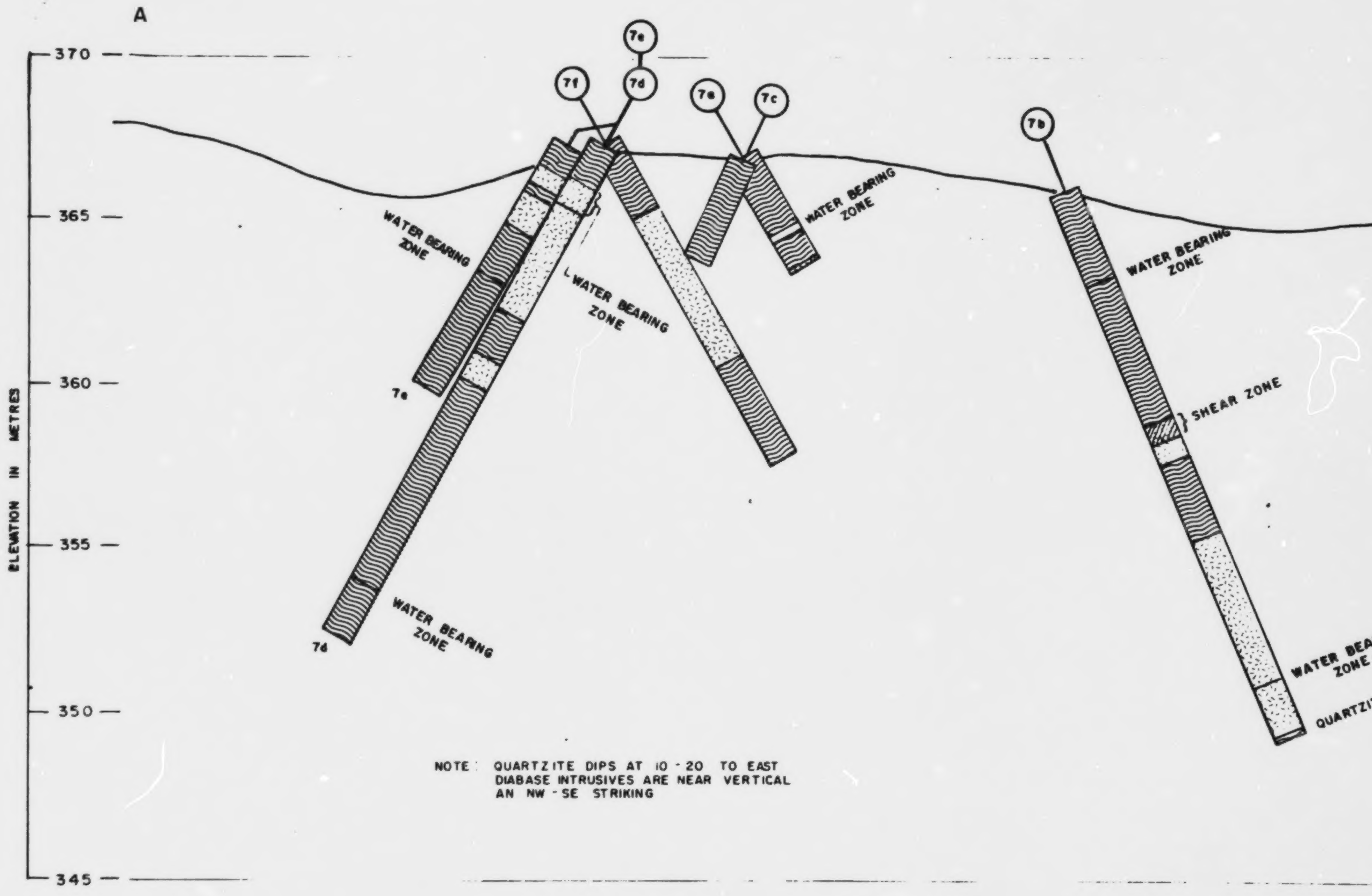
When the boreholes were advanced into the underlying soils, bentonite seals were installed at the tailings/soil interface. Where possible or necessary, these boreholes were flushed with water from Dumbell Lake during drilling.


BH. SO-7a
BH. SO-7c
QUARTZITE OUTCROP
SWAMP
QUARTZITE OUTCROPIN
BH. SO-7b
A
QUARTZITE OUTCRO
OVERBURDEN
QUARTZITE OUTCROP
QUARTZITE OUTCROP
QUARTZITE
DIABASE
BH. SO-7d
QUARTZITE
BH. SO-7f
DIABASE
DIABASE
BH. SO - 7e
QUARTZITE
DIABASE OUTCROP

PLAN

SCALE 1:125


STREAM BED
QUARTZITE OUTCROPINGS
BH. SO-7b
QUARTZITE
DIABASE
A
2 WEIR STRUCTURE
QUARTZITE OUTCROP

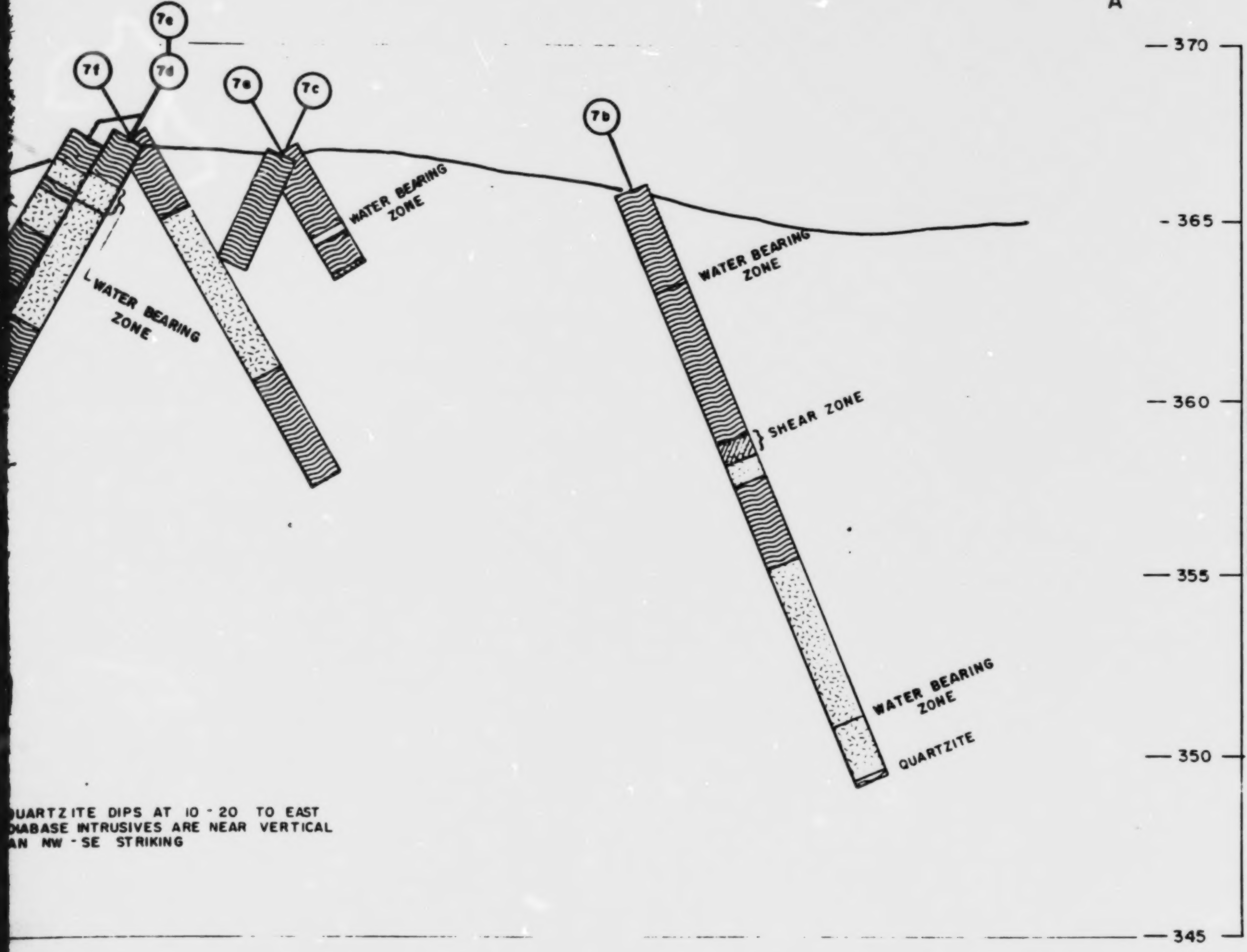

A
370
365
360
355
350
345
ELEVATION IN METRES
7e
7f
7d
7e
7c
7b
WATER BEARING ZONE
WATER BEARING ZONE
WATER BEARING ZONE
WATER BEARING ZONE
WATER BEARING ZONE
SHEAR ZONE
WATER BEA
ZONE
QUARTZI
7e
7d

NOTE : QUARTZITE DIPS AT 10 - 20 TO EAST
DIABASE INTRUSIVES ARE NEAR VERTICAL
AN NW - SE STRIKING

SECTION A-A

PLAN AND CROSS SECTION SO-07

FIGURE I. 9


A'
7e
7f
7d
7a
7c
7b
WATER BEARING ZONE
WATER BEARING ZONE
WATER BEARING ZONE
SHEAR ZONE
WATER BEARING ZONE
QUARTZITE
370
365
360
355
350
345
ELEVATION IN METRES

UARTZITE DIPS AT 10 - 20 TO EAST
DIABASE INTRUSIVES ARE NEAR VERTICAL
AN NW - SE STRIKING

SECTION A-A

LEGEND

○	BOREHOLE IN ELEVATION
⊥	WATER LEVEL IN BOREHOLE, REFER TO SUMMARY OF BOREHOLE SHEETS FOR DETAILS.

LITHOLOGY

▨	UPPER MISSISSAGI FORMATION, QUARTZITE
☐	NIPISSING DIABASE
*	WATER BEARING ZONE

SCALE

1 : 125 (APPROX.)

Date AUG. 30, 1985
Project 841-1334

Golder Associates

Drawn D. M.
Chkd

Piezometers installed in the two cored bedrock holes beneath the tailings and in the nine holes in the stream valleys utilized 3.18 cm I.D. threaded pipe but employed 0.6 m to 2.1 m long intake screens consisting of 0.025 cm slotted 3.18 cm diameter pipe, capped on the lower end. Those installed in the cored holes below the tailings were wrapped with a geotextile filter cloth, while those installed in the surrounding bedrock had no filter cloth wrap.

Subsequent to the positioning of the piezometer in the borehole, the annulus between the piezometer and borehole wall was filled with coarse silica sand. In the boreholes beneath the tailings, bentonite seals were installed at the soil/rock interface and again at the tailings/soil interface.

In the boreholes in the stream valleys it was found to be virtually impossible to place any bentonite below the first wet seam encountered in the borehole, usually at an inclined depth between 3.5 and 6 m (see the Record of oreholes).

At Borehole SO-02, eight piezometers from a previous investigation of subsurface conditions in the Lacnor tailings were incorporated in the monitoring network. The piezometers ranged in depth from 2.0 to 8.2m below the tailings surface and were constructed in a similar manner to those used for this study. The eight piezometers were installed in the early 1980's using a portable vibratory drill (Dubrovsky, et al., 1985). An additional five piezometers were installed at Borehole SO-02 during the drilling program for this study.

Following installation, the piezometers at each borehole location were used to measure water levels and/or for the collection of porewater samples for chemical analyses.

For each borehole location, the prefixes WL and GW were used to refer to water levels and porewater samples respectively from particular piezometers. For example, WL-01a and GW-01a referred to water levels and porewater/groundwater samples from the piezometer in Borehole SO-01a.

1.5.2 Water Level Measurements

Water level measurements were made at approximately monthly intervals in all monitoring wells. Measurements were made using a standard electrical water level finder. The results are given on Table 1.6. In the fine grained tailings and sub-tailings soil and rock, the first measurements may have been taken prior to complete equilibrium (for example, the April 1985 reading of 3.33 m at piezometer WL-01c appears to be abnormally low). In addition, the abnormally high pond levels between April and June 1985 influenced water levels in piezometers, especially those within several metres of the tailings surface, in the eastern part of the tailings basin.

Water levels in the monitoring wells installed in and below the tailings generally decreased by 0.5 to 1.0 m between April and July, generally reaching their lowest measured levels in July. The highest water levels were generally recorded in March or April. These variations are consistent with observations made at other tailings basins in the Elliot Lake area (Cherry, et al., 1980, Dubrovksy, et al., 1985).

The static water levels in the off-tailings rock monitoring wells, presented on Table 1.7, were generally between 0.5 and 4 m of ground surface. These water levels showed a greater degree of fluctuation than the water levels in the monitoring wells in the tailings, varying by up to 3.5 m. The piezometric levels were also influenced by the subsurface geology and showed no consistent trends of vertical hydraulic gradients.

Within and below the tailings vertical hydraulic gradients were low but generally slightly downward at WL-01, 02, 03 and 04. The vertical hydraulic gradients within the tailings at site WL-05 were also low. The water levels in the sub-tailings piezometers at site WL-05 (Piezometers 5a, 5b and 5c) were 2 m lower than the water levels in the piezometers in the tailings.

This difference in water levels between the piezometers within and beneath the

Table 1.6 TAILINGS POREWATER PIEZOMETER AND WATER LEVEL DATA - LACNOR

SITE	MONITORING WELL	ELEVATIONS (m ASL)		PIPE STICK UP	DEPTH TO BOTTOM OF INTAKE SCREEN				WATER LEVEL DATA IN THE MONITORING WELLS DEPTH TO WATER (BGS) m					
		GROUND SURFACE	TOP OF PIPE	(m AGS)	(m BGS)	MAR	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV
WL-01	a	-	386.12	1.21	7.80	-	0.38	0.49	0.74	0.96	-	0.82	-	1.78
	b	-	386.13	1.20	11.84	-	0.59	0.66	0.89	1.19	-	1.09	-	1.73
	c	-	385.98	0.97	6.50	-	3.33	0.43	0.64	1.02	-	0.83	-	1.22
	d	-	385.29	0.27	4.24	-	0.43	0.51	0.74	1.04	-	0.87	-	0.48
	e	-	385.51	0.43	2.57	-	0.46	0.53	0.79	1.07	-	0.92	-	0.51
	f	385.06	385.30	0.21	1.24	-	0.43	0.53	0.74	1.04	-	0.91	-	0.61
WL-02	a	-	384.03	0.61	16.11	-	0.41	0.49	0.79	1.17	-	1.01	-	1.01
	b	-	384.94	0.53	14.48	-	0.51	0.59	0.84	1.14	-	0.99	-	0.97
	c	-	384.20	0.74	10.36	-	0.41	0.49	0.79	1.07	-	0.91	-	1.07
	d	-	384.87	0.46	2.60	-	0.35	0.46	0.74	1.02	-	0.84	-	0.71
	e	383.45	384.92	0.41	1.02	-	0.38	0.46	0.74	0.99	-	0.89	-	0.71
WL-02	i	-	384.49	1.19	7.90	0 .41	-	-	0.56	0.86	-	0.74	-	1.32
	ii	-	384.20	0.89	7.52	0 .41	-	-	0.56	0.86	-	0.73	-	1.01
	iii	-	384.48	1.19	6.60	0 .41	-	-	0.56	0.86	-	0.74	-	1.30
	iv	-	383.86	0.56	5.51	-	-	-	0.61	0.89	-	0.71	-	0.71
	v	-	384.68	1.40	3.58	0 .41	-	-	0.56	0.81	-	0.68	-	1.78
	vi	-	384.66	1.35	4.60	0 .46	-	-	0.61	0.86	-	0.73	-	1.47

NOTES:

DATE OF WATER LEVEL READINGS

WL-01 APR. 4, MAY 6, JUNE 4, JULY 17, SEPT. 25, NOV. 7
WL-02 APR. 3, MAY 6, JUNE 6, JULY 18, SEPT. 25, NOV. 7
WL-02 i to viii MAR.23, MAY 6, JUNE 6, JULY 17, SEPT. 25, NOV. 7

Table 1.6 TAILINGS POREWATER PIEZOMETER AND WATER LEVEL DATA - LACNOR - Page Two

SITE	MONITORING WELL	ELEVATIONS (m ASL) GROUND SURFACE	ELEVATIONS (m ASL) TOP OF PIPE	PIPE STICK UP (m AGS)	DEPTH TO BOTTOM OF INTAKE SCREEN (m BGS)	MAR	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV
						WATER LEVEL DATA IN THE MONITORING WELLS DEPTH TO WATER (BGS) m								
WL-02	vii		383.90	0.58	2.62	-	-	-	0.63	0.86	-	0.74	-	0.71
	viii	383.45	384.68	1.40	1.48	0.43	-	-	0.61	0.86	-	0.71	-	1.47
WL-03	a	379.54	380.14	0.53	12.27	+0.41	-(1)	+0.28(2)	+0.23(3)	0.46(4)	-	0.33	-	0.25
	b	-	380.34	0.81	10.52	+0.30	-	+0.33	+0.26	0.36	-	0.20	-	0.46
	c	-	380.39	0.84	8.97	+0.27	-	+0.28	+0.23	0.33	-	0.17	-	0.63
	d	-	380.19	0.63	7.67	+0.33	-	+0.30	+0.23	0.56	-	0.18	-	0.46
	e	-	380.25	0.68	6.12	+0.08	-	+0.30	+0.20	0.28	-	0.13	-	0.51
	f	-	380.22	0.66	4.62	+0.35	-	+0.30	+0.20	0.30	-	0.15	-	0.56
	g	-	380.33	0.76	3.05	+0.33	-	+0.28	+0.20	0.28	-	0.10	-	0.69
	h	-	380.83	1.29	0.99	+0.33	-	+0.30	+0.38	0.28	-	0.08	-	1.24
WL-04	a	-	381.87	0.91	11.89	-	0.15	0.26	0.33	0.61	-	0.49	-	1.12
	b	-	381.39	0.31	8.81	-	0.15	0.33	0.43	0.66	-	0.58	-	0.61
	c	-	381.31	0.38	7.32	-	0.10	0.36	0.46	0.63	-	0.46	-	0.51
	d	-	381.55	0.58	6.20	-	0.10	0.43	0.51	0.68	-	0.49	-	0.84
	e	-	381.52	0.56	4.14	-	0.13	0.48	0.53	0.71	-	0.48	-	0.71
	f	-	381.36	0.38	2.82	-	0.15	0.58	0.61	0.79	-	0.48	-	0.61
	g	380.97	381.38	0.41	1.27	-	0.10	0.66	0.66	0.81	-	0.50	-	0.66

DATE OF WATER LEVEL READINGS

WL-02 i to viii	MAR. 23, JUNE 6, JULY 18, SEPT. 25, NOV. 7
WL-03	APR. 3, JUNE 4, JULY 18, SEPT. 25, NOV. 7
WL-04	APR. 3, MAY 6, JUNE 6, JULY 18, SEPT. 25, NOV. 7

Notes

1) At Site WL-03 All Installations Were Frozen
2) At SiteWL-03 Ponded Surface Water to +0.3 m
3) At Site WL-03 Ponded Surface Water to +0.25m
4) No ponded Surface Water

Table 1.6 TAILINGS POREWATER PIEZOMETER AND WATER LEVEL DATA - LACNOR - Page Three

SITE	MONITORING WELL	ELEVATIONS (m ASL)		PIPE STICK UP	DEPTH TO BOTTOM OF INTAKE SCREEN	WATER LEVEL DATA IN THE MONITORING WELLS								
						DEPTH TO WATER (BGS) m								
		GROUND SURFACE	TOP OF PIPE	(m AGS)	(m BGS)	MAR	APR	MAY	JUNE	JUL	AUG	SEP	OCT	NOV
WL-05	a	382.71	380.40	0.51	18.34	-	3.25	-	3.18	4.22	-	4.01	-	3.86
	b	-	380.31	0.43	28.42	-	2.54	-	3.02	3.55	-	3.33	-	3.05
	c	-	380.53	0.66	22.10	-	3.02	-	3.20	4.07	-	3.86	-	3.81
	d	-	380.27	0.41	10.90	-	0.87	-	1.09	1.78	-	1.52	-	1.37
	e	-	380.49	0.58	9.24	-	0.76	-	0.99	1.75	-	1.45	-	1.47
	f	-	380.23	0.38	7.95	-	0.63	-	0.84	1.55	-	1.27	-	1.12
	g	-	-	-	NO INSTALLATION	-	-	-	-	-	-	-	-	-
	h	-	380.54	0.66	6.07	-	0.48	-	0.71	1.40	-	1.14	-	1.24
	i	-	383.19	0.33	4.32	-	0.33	-	0.48	1.19	-	0.61	-	0.76
	j	-	383.20	0.33	2.79	-	0.18	-	0.28	1.04	-	0.38	-	0.61
	k	-	383.36	0.51	1.12	-	0.00	-	0.08	0.86	-	0.46	-	0.66

NOTES:

DATE OF WATER LEVEL READINGS

WL-05 APR. 3, JUNE 11, JULY 18, SEPT. 25, NOV. 7

Table 1.7 OFF-TAILINGS GROUNDWATER PIEZOMETER AND WATER LEVEL DATA - LACNOR

SITE	INCLINATION (DEG.)	MONITORING WELL	ELEVATIONS (m ASL) GROUND SURFACE	ELEVATIONS (m ASL) TOP OF PIPE	INCLINED PIPE STICK UP (m AGS)	INCLINED DEPTH TO BOTTOM OF INTAKE SCREEN (m BGS)	MAR	APR	MAY	WATER LEVEL DATA IN THE MONITORING WELLS DEPTH TO WATER (BGS) m JUNE	JUL	AUG	SEP	OCT	NOV
WL-06	68	a	371.27	372.46	1.32	31.15	-	-	-	23.82 (22.09)	+0.33 (+0.3)	-	+0.43 (+0.40)	-	0.69 (0.64)
	55	b	371.41	371.93	0.65	16.44	-	-	-	1.37 (1.12)	1.30 (1.06)	-	1.20 (0.98)	-	1.62 (1.33)
	65	c	371.57	372.27	0.81	8.77	-	-	-	1.60 (1.45)	1.55 (1.40)	-	1.42 (1.29)	-	1.96 (1.78)
WL-07	61	a	366.67	368.04	1.24	3.83	-	-	-	1.70 (1.49)	1.73 (1.51)	-	1.78 (1.56)	-	2.39 (2.09)
	67	b	365.84	367.27	1.63	17.91	-	-	-	1.19 (1.10)	0.64 (0.58)	-	0.88 (0.81)	-	2.57 (2.37)
	65	c	366.79	368.22	1.63	3.40	-	-	-	1.45 (1.31)	0.61 (0.55)	-	1.24 (1.12)	-	2.51 (2.27)
	62	d	367.31	368.11	0.91	15.67	-	-	-	2.29 (2.02)	0.84 (0.74)	-	2.49 (2.20)	-	2.82 (2.49)
	62	e	367.18	368.07	0.99	8.61	-	-	-	2.29 (2.02)	+0.03 (+0.02)	-	2.62 (2.31)	-	3.20 (2.83)
	60	f	367.28	368.26	1.14	9.40	-	-	-	3.43 (2.97)	0.64 (0.55)	-	3.33 (2.88)	-	4.29 (3.72)

NOTES:

DATE OF WATER LEVEL READINGS

WL-06 JUNE 13, JULY 18, SEPT. 25, NOV. 7
WL-07 JUNE 13, JULY 18, SEPT. 25, NOV. 7

tailings at Borehole SO-05 occurred across a zone of peat at the base of the tailings, a feature not present at the other borehole locations across the tailings area. In general, however, there was a tendency for downward flow of groundwater through the tailings to the underlying sub-tailings soils across the Lacnor basin.

1.5.3 Hydraulic Conductivity Measurements

Rising head hydraulic conductivity tests were carried out in various piezometers subsequent to their installation. In addition, falling head tests employing mechanical packers were conducted within the borehole at two depths in the bedrock during the drilling of Borehole SO-05b.

The data from these tests were used to calculate hydraulic conductivities, using the Hvorslev method (1951). The results are listed in Tables 1.8 and 1.9 together with the pertinent data used in the calculations.

The *in situ* hydraulic conductivity tests for the various tailings, sub-tailings and off-tailings geological materials are summarized below:

Fine Tailings	2×10^{-6} to 2×10^{-5} cm/s
Coarse Tailings	1×10^{-5} to 5×10^{-4} cm/s
Sand and Gravel below Tailings	8×10^{-4} to 1×10^{-3} cm/s
Bedrock	3×10^{-7} to 3×10^{-3} cm/s

Good agreement was obtained between the results of falling head hydraulic conductivity tests with packers in Borehole SO-05b and subsequent rising head tests on the piezometer installed in rock in the same borehole.

The *in situ* hydraulic conductivity tests in the tailings yielded hydraulic conductivity values which were generally lower than those determined from laboratory constant head permeameter tests on samples of coarse and fine

Table 1.8 - TAILINGS POREWATER - PIEZOMETER AND HYDRAULIC CONDUCTIVITY DATA - LACNOR

SITE	MONITORING WELL	ELEVATIONS (ASL) m		PIPE STICK UP	DEPTH TO BOTTOM OF INTAKE SCREEN	SCREEN LENGTH	SAND PACK LENGTH	HYDRAULIC CONDUCTIVITY TESTING (K)			
		GROUND SURFACE	TOP OF PIPE	(AGS) m	(BGS) m	(cm)	(LOCATION) (BGS) m	TEST TYPE	CALCULATED T (s)	CALCULATED K (cm/s)	MATERIAL TYPE
WL-01	a	-	386.12	1.21	7.80	12.7	NONE	1 1	8800 4500	$1.8 * 10^{-5}$ $3.6 * 10^{-5}$	1&2(FILL)
	b	-	386.13	1.20	11.84	100	3.89	2 2	54 75	$3.0 * 10^{-3}$ $2.0 * 10^{-4}$	7
	c	-	385.98	0.97	6.50	12.7	NONE	1	400	$4.0 * 10^{-4}$	2
	d	-	385.29	0.27	4.24	12.7	NONE	1	410	$3.9 * 10^{-4}$	2
	e	-	385.51	0.43	2.57	12.7	NONE	1	330	$4.9 * 10^{-4}$	2
	f	385.06	385.30	0.21	1.24	12.7	NONE	1	1650	$9.7 * 10^{-5}$	2
WL-02	a	-	384.03	0.61	16.11	12.7	1.14	1	315	$5.1 * 10^{-4}$	4
	b	-	384.94	0.53	14.48	12.7	NONE	1	310	$5.2 * 10^{-4}$	2
	c	-	384.20	0.74	10.36	12.7	NONE	1	530	$3.0 * 10^{-4}$	2
	d	-	384.87	0.46	2.60	12.7	NONE	1	355	$4.5 * 10^{-4}$	2
	e	383.45	384.92	0.41	1.02	12.7	NONE	1	310	$5.2 * 10^{-4}$	2
WL-02	i	-	384.49	1.19	7.90	UNKNOWN EST. 12.7	UNKNOWN ASSUMED AS ABOVE	1	240	$6.7 * 10^{-4}$	UNKNOWN ASSUMED AS ABOVE
	ii	-	384.20	0.89	7.52		NONE	1	-	-	
	iii	-	384.48	1.19	6.60	"	NONE	1	460	$3.5 * 10^{-4}$	2
	iv	-	383.86	0.56	5.51	"	NONE	1	-	-	2
	v	-	384.68	1.40	3.58	"	NONE	1	7200	$2.2 * 10^{-5}$	2
	vi	-	384.66	1.35	4.60	"	NONE	1	2050	$7.8 * 10^{-5}$	2

NOTES:

ABBREVIATIONS

ASL - ABOVE SEA LEVEL
AGS - ABOVE GROUND SURFACE
BGS - BELOW GROUND SURFACE
T - BASIC TIME LAG (HVORSLEV, 1951)

TEST TYPE:

1- RISING HEAD IN PIEZO.
2- RISING HEAD IN PIEZO. IN ROCK
3- FALLING HEAD IN BH. WITH PACKERS
4- LABORATORY TEST

MATERIAL TYPE:

1- FINE TAILING, SLIMES, VERY FINE SILTS.
2- COARSE TAILINGS, SANDS, SILTS.
3- INTERLAYERED FINE &COARSE TAILINGS.
4- TILL
5- FINE SANDS AND SILTS.
6- SANDS AND GRAVELS.

Table 1.8 - TAILINGS POREWATER - PIEZOMETER AND HYDRAULIC CONDUCTIVITY DATA - LACNOR - Page Two

SITE	MONITORING WELL	ELEVATIONS (ASL) m		PIPE STICK UP	DEPTH TO BOTTOM OF INTAKE SCREEN	SCREEN LENGTH	SAND PACK LENGTH	HYDRAULIC CONDUCTIVITY TESTING (K)			
		GROUND SURFACE	TOP OF PIPE	(AGS) m	(BGS) m	(cm)	(LOCATION) (BGS) m	TEST TYPE	CALCULATED T (s)	CALCULATED K (cm/s)	MATERIAL TYPE
WL-02	vii		383.90	0.58	2.62	UNKNOWN	UNKNOWN	1	500	3.2 * 10-4	2
	viii	383.45	384.68	1.40	1.48	EST. 12.7	ASSUMED AS ABOVE NONE	1	1150	1.4 * 10-4	2
WL-03	a	379.54	380.14	0.53	12.27	12.7	NONE	1	2400	6.7 * 10-5	4
	b	-	380.34	0.81	10.52	12.7	NONE	-	-	-	1
	c	-	380.39	0.84	8.97	12.7	NONE	1	6600	2.4 * 10-6	1
	d	-	380.19	0.63	7.67	12.7	NONE	1	82800	1.9 * 10-6	1
	e	-	380.25	0.68	6.12	12.7	NONE	1	21000 13800	7.6 * 10-6 1.2 * 10-5	1 3
	f	-	380.22	0.66	4.62	12.7	NONE	1	7500	2.1 * 10-5	1
	g	-	380.33	0.76	3.05	12.7	NONE	1	9600	1.7 * 10-5	1
	h	-	380.83	1.29	0.99	12.7	NONE	1	690	2.3 * 10-4	2
WL-04	a	-	381.87	0.91	11.89	12.7	1.45	1	5600	2.9 * 10-5	4
	b	-	381.39	0.31	8.81	12.7	NONE	1	10500	1.5 * 10-5	1
	c	-	381.31	0.38	7.32	12.7	NONE	1	8820	1.8 * 10-5	1
	d	-	381.55	0.58	6.20	12.7	NONE	1	7800	2.1 * 10-5	1
	e	-	381.52	0.56	4.14	12.7	NONE	1	13800	1.2 * 10-5	3
	f	-	381.36	0.38	2.82	12.7	NONE	1	3300	4.9 * 10-5	3
	g	380.97	381.38	0.41	1.27	12.7	NONE	1	1500	1.1 * 10-4	2

NOTES:

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(HVORSLEV, 1951)

TEST TYPE:
1- RISING HEAD IN PIEZO.
2- RISING HEAD IN PIEZO. IN ROCK
3- FALLING HEAD IN BH. WITH PACKERS
4- LABORATORY TEST

MATERIAL TYPE:
1- FINE TAILING, SLIMES, VERY FINE SILTS.
2- COARSE TAILINGS, SANDS, SILTS.
3- INTERLAYERED FINE &COARSE TAILINGS.
4- TILL
5- FINE SANDS AND SILTS.
6- SANDS AND GRAVELS.
7-QUARTZITE BEDROCK
8-DIABASE BEDROCK

Table 1.8 - TAILINGS POREWATER - PIEZOMETER AND HYDRAULIC CONDUCTIVITY DATA - LACNOR - Page Three

SITE	MONITORING WELL	ELEVATIONS (ASL) m		PIPE STICK UP	DEPTH TO BOTTOM OF INTAKE SCREEN	SCREEN LENGTH	SAND PACK LENGTH	HYDRAULIC CONDUCTIVITY TESTING (K)			
									CALCULATED		
		GROUND SURFACE	TOP OF PIPE	(AGS) m	(BGS) m	(cm)	(LOCATION) (BGS) m	TEST TYPE	T (s)	K (cm/s)	MATERIAL TYPE
WL-05	a	382,71	380,40	0,51	18,34	12,7	NONE	1	120	1,3 * 10-3	6
								1	192	8,3 * 10-4	6
	b	-	380,31	0,43	28,42	100	6,9	1	192	6,1 * 10-6	7
							(30,4-23,5)	2	1300	7,3 * 10-6	7
							3,05	3	780	7,5 * 10-6	7
							(30,4-27,4)				
							3,05	3	4200	8,5 * 10-6	7
							(27,4-24,4)				
	c	-	380,53	0,66	22,10	12,7	NONE	1	21000	7,6 * 10-6	5
	d	-	380,23	0,41	10,90	12,7	NONE	1	4080	3,9 * 10-5	3
	e	-	380,49	0,58	9,24	12,7	NONE	1	6600	2,4 * 10-5	3
	f	-	380,23	0,38	7,95	12,7	NONE	1	15600	1,0 * 10-5	3
	g	-	-	-	NO INSTALLATION	-	-	-	-	-	-
	h	-	380,54	0,66	6,07	12,7	NONE	1	14100	1,1 * 10-5	1
	i	-	383,19	0,33	4,32	12,7	NONE	1	13080	1,2 * 10-5	1
	j	-	383,20	0,33	2,79	12,7	NONE	1	11760	1,4 * 10-5	1
	k	-	383,36	0,51	1,12	12,7	NONE	1	1584	1,0 * 10-4	2

NOTES:

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4- LABORATORY TEST

MATERIAL TYPE:
1- FINE TAILING, SLIMES, VERY FINE SILTS.
2- COARSE TAILINGS, SANDS, SILTS.
3- INTERLAYERED FINE &COARSE TAILINGS.
4- TILL
5- FINE SANDS AND SILTS.
6- SANDS AND GRAVELS.
7-QUARTZITE BEDROCK
8-DIABASE BEDROCK

Table 1.9 - OFF-TAILINGS GROUNDWATER - PIEZOMETER AND HYDRAULIC CONDUCTIVITY DATA

SITE	MONITORING WELL	INCLINATION (DEG.)	ELEVATIONS (ASL) m GROUND SURFACE	ELEVATIONS (ASL) m TOP OF PIPE	INCLINED PIPE STICK UP (AGS) m	INCLINED DEPTH TO BOTTOM OF INTAKE SCREEN (BGS) m	INCLINED SCREEN LENGTH (cm)	INCLINED SAND PACK LENGTH [LOCATION] (BGS) m	HYDRAULIC CONDUCTIVITY TESTING (K) TEST TYPE	CALCULATED T (s)	CALCULATED K (cm/s)	MATERIAL TYPE
WL-06	a	68	371.27	372.46	1.32	31.15	2.13	25.64 [6.71-32.34]	-	-	NOT TESTED	7
	b	55	371.41	371.93	0.65	16.44	2.13	13.89 [3.96-17.86]	2	244	2.5 * 10-5	7
	c	65	371.57	372.27	0.81	8.77	2.13	8.46 [0.30-8.77]	2	22500	3.5 * 10-7	7
WL-07	a	61	366.67	368.04	1.24	3.83	0.61	1.39 [2.44-3.83]	2	31.5	1.0 * 10-3	7 & 8
	b	67	365.84	367.27	1.63	17.91	1.52	14.84 [3.03-17.89]	2	3960	2.0 * 10-6	7 & 8
	c	65	366.79	368.22	1.63	3.40	0.61	1.35 [0.61-1.96]	-	-	-	7
	d	62	367.31	368.11	0.91	15.67	1.52	14.73 [2.44-17.17]	2	670	7.6 * 10-6	7 & 8
	e	62	367.18	368.07	0.99	8.61	0.61	4.05 [4.57-8.63]	2	4200	3.5 * 10-6	7 & 8
	f	60	367.28	368.26	1.14	9.40	1.52	6.31 [4.57-10.88]	2	180	5.7 * 10-5	7 & 8

NOTES:

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TEST TYPE:
1- RISING HEAD IN PIEZO.
2- RISING HEAD IN PIEZO. IN ROCK
3- FALLING HEAD IN BH. WITH PACKERS
4- LABORATORY TEST

¶ IN SOME CASES THE SAND PACK ZONE CONSISTS OF BOTH A SECTION OF SAND BACKFILL AND OPEN BOREHOLE BELOW THE BENTONITE SEAL.

¶ MATERIAL TYPE:
1-FINE TAILINGS, SLIMES, VERY FINE SILTS.
2-COARSE TAILINGS, SANDS, SILTS.
3-INTERLAYERED FINE & COARSE TAILINGS.
4-TILL.
5-FINE SANDS AND SILTS.
6-SANDS AND GRAVELS.
7-QUARTZITE BEDROCK.
8-DIABASE BEDROCK.

tailings. (Laboratory values of hydraulic conductivity of 10^{-3} and 10^{-5} cm/s were determined for coarse and fine tailings respectively.)

1.5.4 Porewater/Groundwater Sampling Program

Sets of porewater and groundwater samples were collected in the spring and in the summer of 1985. The spring set was collected between June 11 and 14, 1985. This was slightly later than originally proposed due to the flooding of the Lacnor basin while a downstream decant at the Nordic Mine was being repaired. The summer set of samples was collected between August 19 and 21, 1985. The sampling methodology is described below.

In June, 40 porewater and groundwater samples were collected. Four of these were duplicate samples that were sent to the check laboratory for analysis, two were field blanks of distilled water and one was a surface water sample from Dumbell Lake because water from this source was used for the drilling of several of the deeper boreholes. The remaining 32 samples were collected from tailings, sub-tailings, and off-tailings piezometers. The list of the sites sampled is presented on Table 1.10, along with the results of the sample analyses.

In August, 18 water samples, including 2 duplicate samples, were collected from 16 of the tailings and sub-tailings piezometers. pH and electrical conductance were measured in the porewater in 13 additional piezometers to provide complete pH and electrical conductance profiles in all piezometers at sites GW-02 and GW-05. The list of sites sampled is presented on Table 1.11, along with the results of the sample analyses.

Temperature, pH, electrical conductivity, dissolved oxygen, Eh, acidity and concentrations of ferrous iron were determined in the field. The suite of chemical analyses of the porewater and groundwater samples also included major cations and metals (silver, aluminum, arsenic, boron, beryllium, cadmium, cobalt, chromium, copper, iron, potassium, magnesium, manganese, molybdenum, sodium, nickel, phosphorus, lead, selenium, silicon, strontium, thorium,

Table 1.10 - POREWATER - PHYSICAL, CHEMICAL AND RADIOLOGICAL ANALYSIS RESULTS FOR JUNE SAMPLES

POREWATER CHEMISTRY (JUNE READINGS)

SITE	PIEZO-METER	TIP MATERIAL	DEPTH (m)	TEMP (°C)	DO (ppm)	pH	E.C.@25 C (uS/cm)	Fe 2+ (ppm)	ACIDITY (ppm CaCO3)	Ag mg/L	Al mg/L	As ug/L	B mg/L	Ba mg/L	Be mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L	Cu mg/L	Fe mg/L
GW-01	a	ST-T	7.80	6.5	0.45	5.9	10000	4190	7000	<.05	5.2	4	<.04	<.05	<.005	453	<.1	<.5	1.7	.08	4740
GW-01	b	R	11.84	7.0	0.80	4.9	8400	3410	6100	<.05	13.9	6	<.04	<.05	<.005	481	<.1	.9	1.4	<.08	3830
GW-01	b	DUPLICATE								.04	13.3	20	1.45/1.33	.05	<.01	430	0.78	.77	.06	.045	3400
GW-01	e	T	2.57	6.5	0.80	<2.0	9400	890	1850	<.05	70.1	100	<.04	<.05	<.005	480	<.1	1.4	.5	<.08	958
GW-01	g	BLANK	-							<.005	.20	<1	<.004	.425	<.0005	.30	<.01	.14	.06	.019	.53
GW-01	h	BLANK	-							<.005	.20	<1	<.004	.364	<.0005	.24	<.01	.13	.02	.011	<.01
GW-02	a	ST	16.11	7.0	0.55	5.5	4970	1900	3340	<.05	1.7	6	<.04	<.05	<.005	453	<.1	<.5	.7	<.08	2040
GW-02	b	T	14.48	7.0	0.60	5.2	9010	4690	8800	<.05	35.8	4	<.04	<.05	.012	445	<.1	2.1	1.7	.17	4700
GW-02	c	T	10.36	7.0	0.70	5.75	4090	1620	3200	<.05	41.8	5	<.04	<.05	.021	483	<.1	4.7	.7	.18	1670
GW-02	e	T	1.02	12.0	1.25	<2.0	6800			<.05	16.5	110	<.04	<.05	<.005	559	<.1	.5	.2	.17	348
GW-02	i	T	7.90	8.0	0.95	5.0	5810	1790	6650	<.05	388	20	<.04	<.05	.075	451	<.1	4.0	.9	.10	1910
GW-02	i	DUPLICATE								.05	350	20	.82	.03	.08	410	.43	1.91	.21	.02	1760
GW-02	iii	T	6.60	6.0	0.60	4.15	4880	1340	3750	<.05	251	17	<.04	<.05	.011	473	<.1	2.0	.6	<.08	1420
GW-02	iv	T	5.51	6.0	0.65	3.95	5800	1620	4650	<.05	416	180	<.04	<.05	.009	454	<.1	2.6	3.8	<.08	1780
GW-02	v	T	3.58	6.0	1.20	1.75	13200	1285	2900	<.05	98.8	7	<.04	<.05	.005	459	<.1	2.4	.9	<.08	1410
GW-02	vi	T	4.60	6.5	1.70	2.3	9800	1560	4300	<.05	261	205	<.04	<.05	.009	454	<.1	2.5	3.4	<.08	1700
GW-02	vii	T	2.62	7.5	1.80	2.1	13200	1510	3200	<.05	98.7	80	<.04	<.05	<.005	474	<.1	2.3	.9	<.08	1640
GW-02	viii	T	1.48	9.0	0.90	<2.0	15000			<.05	54.3	800	<.04	.06	<.005	489	<.1	1.6	.5	.11	1210
GW-04	a	ST-T	11.89	6.5	0.50	5.8	5000	1340	1900	<.05	.5	3	<.04	<.05	<.005	460	<.1	1.2	.6	<.08	1550
GW-04	c	T	7.32	6.0	0.50	7.1	3700	55	2000	<.05	<.1	9	.64	<.05	<.005	538	<.1	.5	<.1	<.08	79.2
GW-04	e	T	4.14	5.5	0.50	6.7	3600	220	150	<.05	<.1	5	.77	<.05	<.005	530	<.1	<.5	.1	<.08	255
GW-04	f	T	2.82	6.0	0.50	6.4	4200	220	500	<.05	<.1	5	.64	<.05	<.005	508	<.1	<.5	<.1	<.08	222
GW-05	a	ST	18.34	6.8	0.50	5.1	7860	4860	8600	<.05	1.8	4	<.04	<.05	<.005	501	<.1	<.5	1.3	.09	5300
GW-05	a	DUPLICATE								.04	2.5	3	1.88/1.85	.03	<.01	460	1.04	.53	.06	.020	4800
GW-05	b	R	28.42	7.0	1.05	3.6	3400	220	500	<.005	<.01	<1	.095	.026	<.0005	122	.01	.17	.02	.010	22.1
GW-05	c	ST	22.10	6.5	0.55	5.4	8050	2850	4950	<.05	<.1	2	<.04	<.05	<.005	463	<.1	<.5	.8	<.08	3140
GW-05	d	T	10.90	6.5	0.40	3.8	7630	6255	10750	<.05	<.1	5	<.04	<.05	<.005	435	<.1	<.5	2.2	.11	6650
GW-05	e	T	9.24	6.8	0.40	3.55	8200	4635	8300	<.05	<.1	4	<.04	<.05	<.005	437	<.1	<.5	1.3	.10	5050
GW-05	f	T	7.95	6.5	0.42	5.7	8300	4020	7050	<.05	<.1	4	<.04	<.05	<.005	434	<.1	<.5	.9	.09	3940
GW-05	h	T	6.07	6.0	0.50	5.9	4000	1005	1750	<.05	<.1	4	<.04	<.05	<.005	480	<.1	<.5	.2	<.08	1070
GW-05	i	T	4.32	5.5	0.50	6.2	5400	1005	2200	.14	.5	4	<.04	<.05	<.005	443	<.1	<.5	.4	<.08	1270
GW-05	j	T	2.79	7.0	0.50	4.3	6400	280	1500	<.05	44.3	12	.15	<.05	.006	427	<.1	.9	.2	<.08	368
GW-05	k	T	1.12	10.8	0.60	4.8	2800	280	800	.12	2.2	90	<.04	.09	<.005	485	<.1	.7	.7	<.08	282
GW-05	l	POND	-	11.0	7.70	2.7	1800			<.005	10.0	2	.017	.079	.0007	114	<.01	.23	.05	.063	71.6
GW-06	b	R	13.47	6.0	0.60	6.65	210	30	100	<.005	.16	1	.069	2.21	<.0005	23.6	<.01	.06	<.01	<.008	3.46
GW-06	c	R	7.95	6.0	9.50	5.8	260														
GW-07	b	R	16.49	6.0	0.70	7.9	210	30	50	<.005	.15	1	.181	.764	<.0005	26.2	<.01	<.05	<.01	<.008	.08
GW-07	d	R	13.84	5.5	0.95	5.45	450	30	100	<.005	.07	2	.041	.136	<.0005	48.9	<.01	.17	<.01	<.008	12.3
GW-07	f	R	8.14	5.2	0.60	7.2	240	110	50	<.005	.07	7	.519	.570	<.0005	25.6	<.01	.07	<.01	<.008	<.01
GW-07	f	DUPLICATE								<.01	.09	15	.41	1.12	<.01	22	<.005	<.01	<.01	.005	.21
GW-08	a	LAKE	-	16.0		8.1	69	140	25	<.005	.09	<1	<.004	1.58	<.0005	9.40	<.01	.09	<.01	.009	<.01

Table 1.10 - POREWATER - PHYSICAL, CHEMICAL AND RADIOLOGICAL ANALYSIS RESULTS FOR JUNE SAMPLES - Page Two

SITE	PIEZO-METER	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Mo (mg/L)	Na (mg/L)	Ni (mg/L)	P (mg/L)	Pb (mg/L)	Se (ug/L)	Si (mg/L)	Sr (mg/L)	Th (mg/L)	Ti (mg/L)	V (mg/L)	Zn (mg/L)	Zr (mg/L)	F^- (mg/L)	Cl^- (mg/L)
GW-01	a	140	171	16.4	<2	30	<.5	<5	<.05	<1	8.6	.90	1.0	.27	.31	1.9	.8	6.50	26.0
GW-01	b	110	203	24.2	3	40	<.5	<5	<.05	<1	7.4	1.14	<.5	.06	.27	2.8	<.5	3.20	27.0
GW-01	b	123	190	23	.28	56	.42	.28/.34	0.83	<1	16.3/16.6	.92	N/T	.34/.35	0.07	1.29	1.16	3.1	29.0
GW-01	e	30	33.1	.3	<2	<10	.7	<5	1.50	2	61.4	.45	1.5	2.95	.09	3.4	<.5	1.20	7.00
GW-01	g	2	.07	<.01	.2	1	<.05	<.5	<.05	1	.12	.017	.17	.010	.027	5.57	<.05	.01	1.59
GW-01	h	2	.02	<.01	.2	2	<.05	<.5	<.05	<1	.13	.009	.21	.007	.025	2.48	<.05	.02	1.53
GW-02	a	50	109	13.0	<2	10	<.5	<5	<.05	<1	8.1	.70	<.5	<.05	.18	1.7	<.5	2.40	8.00
GW-02	b	160	236	15.1	4	50	<.5	<5	<.05	<1	23.4	.84	4.4	2.97	.39	1.5	8.2	60.7	41.0
GW-02	c	60	103	2.5	5	<10	.9	<5	<.05	<1	20.1	.54	5.6	2.96	.30	7.1	7.6	57.1	8.00
GW-02	e	10	13.4	<.1	<2	<10	<.5	<5	1.65	5	57.0	.30	<.5	.30	.07	8.4	<.5	1.40	1.00
GW-02	i	60	75.2	.7	2	<10	1.6	<5	.35	<1	33.5	.53	2.8	.33	.60	8.4	.8	3.70	11.0
GW-02	i	61	71	.75	.02	16	1.69	.30	1.35	<1	76	.47	N/T	.38	.24	8.4	1.11	0.7	10.1
GW-02	iii	50	69.9	.6	<2	<10	1.1	<5	.35	<1	36.6	.61	1.4	.11	.52	2.6	<.5	1.90	10.0
GW-02	iv	70	62.8	.7	<2	<10	1.8	<5	<.05	<1	72.4	.38	2.3	.10	1.33	2.5	<.5	1.40	15.0
GW-02	v	60	42.4	.4	<2	20	1.1	<5	1.00	1	57.5	.36	10.2	5.15	.23	4.4	<.5	2.20	24.0
GW-02	vi	80	75.3	.6	<2	<10	1.1	<5	2.00	2	64.5	.52	12.1	1.94	.82	3.6	<.5	2.20	14.0
GW-02	vii	50	35.2	.4	<2	20	1.2	<5	.90	1	60.2	.33	8.1	5.47	.23	6.4	<.5	1.40	26.0
GW-02	viii	30	23.4	.3	<2	<10	.7	<5	1.65	2	58.5	.31	1.4	5.04	.14	49.9	<.5	1.40	6.00
GW-04	a	60	187	21.8	<2	70	<.5	<5	<.05	<1	11.7	.96	.8	<.05	.29	2.4	<.5	1.20	49.0
GW-04	c	70	311	8.1	<2	70	<.5	<5	<.05	<1	6.7	.85	.7	<.05	.32	4.0	<.5	5.70	51.0
GW-04	e	70	259	21.1	<2	90	<.5	<5	<.05	<1	6.5	.82	<.5	<.05	.21	2.1	<.5	3.40	62.0
GW-04	f	70	341	10.5	<2	150	<.5	<5	<.05	<1	6.8	.69	<.5	<.05	.24	3.3	<.5	5.00	114
GW-05	a	90	258	13.7	<2	40	<.5	<5	<.05	<1	7.1	1.20	.6	.17	.31	2.1	.5	5.00	37.0
GW-05	a	104	250	12.8	.34	55	0.38	.23	1.05	<1	17.6	.87	N/T	.40	.09	.47	1.74/1.76	5.00	25.0
GW-05	b	6	23.3	1.27	.3	40	.06	<.5	<.05	<1	1.02	.282	.26	.005	.045	.39	<.05	.30	40.0
GW-05	c	70	238	19.9	<2	60	<.5	<5	<.05	<1	9.7	1.26	<.5	<.05	.28	1.7	<.5	1.20	41.0
GW-05	d	30	198	7.9	<2	10	<.5	<5	<.05	<1	13.2	1.37	<.5	<.05	.29	1.5	<.5	1.90	6.00
GW-05	e	20	145	4.8	<2	10	<.5	<5	<.05	<1	11.9	1.10	.6	<.05	.26	2.9	<.5	1.90	7.00
GW-05	f	40	96.5	3.7	<2	<10	<.5	<5	<.05	<1	11.0	1.21	.5	<.05	.19	2.3	<.5	1.90	10.0
GW-05	h	40	95.8	5.9	<2	20	<.5	<5	<.05	<1	8.4	.68	<.5	<.05	.12	3.6	<.5	3.30	21.0
GW-05	i	50	432	12.2	<2	20	<.5	<5	<.05	<1	9.9	.57	.9	<.05	.42	2.8	<.5	3.10	26.0
GW-05	j	20	1190	11.2	<2	10	.7	<5	1.50	<1	24.9	.70	1.2	.12	.85	2.3	<.5	5.50	25.0
GW-05	j	20	239	6.0	<2	10	5.3	<5	.80	<1	26.9	.44	.7	<.05	.32	28.2	<.5	3.10	16.0
GW-05	l	7	23.2	1.34	<.2	5	.12	<.5	<.05	<1	5.46	.114	.36	.028	.044	7.94	.06	.70	3.50
GW-06	b	6	8.43	.08	<.2	7	<.05	<.5	<.05	<1	4.80	.143	.10	<.005	.024	11.7	<.05	.26	5.40
GW-06	c																		
GW-07	b	6	9.09	.01	<.2	12	<.05	<.5	<.05	<1	4.37	.311	.10	.005	.026	10.2	<.05	.31	2.34
GW-07	d	9	16.1	1.79	<.2	11	.21	<.5	<.05	<1	8.63	.159	.13	<.005	.025	5.47	<.05	.30	3.00
GW-07	f	6	10.0	.05	<.2	14	<.05	<.5	<.05	<1	4.63	.206	.11	<.005	.019	4.93	<.05	.50	3.80
GW-07	f	9.5	9.7	.06	.01	12.4	.01	.12	<.01	<1	11.6	.18	N/T	.02	<.01	1.22	.03/.05	3.0	4.9
GW-08	a	2	1.62	<.01	<.2	3	<.05	<.5	<.05	<1	.52	.058	.14	.005	.026	5.33	<.05	.07	2.43

Table 1.10 - POREWATER - PHYSICAL, CHEMICAL AND RADIOLOGICAL ANALYSIS RESULTS FOR JUNE SAMPLES - Page Three

										POREWATER CHEMISTRY (JUNE READINGS)								
SITE	PIEZO-METER	PO_4^{3-} (mg/L)	NO^{3-} (mg/L)	NO^{2-} (mg/L)	Br^- (mg/L)	SO_4^{2-} (mg/L)	$SO_4^{2-}(S_4)$ (mg/L)	$SO_4^{2-}(S_5)$ (mg/L)	NH_3-N (mg/L)	U (ppb)	Ra-226 (Bq/L)	Th-228 (Bq/L)	Th-230 (Bq/L)	Th-232 (Bq/L)	Ra-228 (Bq/L)	Po-210 (Bq/L)	Pb-210 (Bq/L)	REDUCED S (mg/L)
GW-01	a	<.1	<.05	<.02	<.1	8640	13400	8720	26.7	4.4	5.90	0.08	9.54	0.08				
GW-01	b	<.1	<.05	<.02	<.1	7840	12100	8050	24.3	5.9	1.65	0.08	1.84	0.08				
GW-01	b	<1	<.5	N/T	<.5	10900	N/T	N/T	20.2	5.0	.39+-.04	<.005	.036+-.012	.006				2000
GW-01	e	<.1	<.05	<.02	<.1	4130	10200	4120	1.70	24.0	5.25	5.20	64.00	5.20				
GW-01	g	<.1	<.05	<.02	<.1	.20	39.0	2.00	.20	1.1	0.03	0.12	0.20	0.12				
GW-01	h	<.1	<.05	<.02	<.1	.10	18.0	1.80	.20	0.5	<0.01	0.15	<0.01	0.15				
GW-02	a	<.1	<.05	<.02	<.1	4470	8980	4660	10.9	0.7	3.35	0.15	4.10	0.15	0.25	0.05	0.32	
GW-02	b	<.1	<.05	<.02	<.1	9750	16200	9340	12.1	59.0	34.00	0.13	21.40	0.13	0.30	0.28	1.32	
GW-02	c	<.1	<.05	<.02	<.1	3860	9520	4070	5.70	2800	38.20	0.08	18.10	0.08	0.60	0.30	2.76	
GW-02	e	<.1	<.05	<.02	<.1	2850	8630	2810	1.60									
GW-02	i	<.1	<.05	<.02	<.1	6650	12700	5840	3.60	9800	15.00	0.66	13.00	0.66	0.80	2.54	16.40	
GW-02	i	<1	<.5	N/T	<.5	6000/6300	N/T	N/T	1.99	13000	2.28+-.13	N/A	1.68+-.07	N/A	2.8+-0.2	2.0+-.02	6.1+-0.3	1830
GW-02	iii	<.1	<.05	<.02	<.1	4800	11200	4930	3.10	1980	17.40	0.45	9.70	0.45	0.60	3.82	21.90	
GW-02	iv	<.1	<.05	<.02	<.1	6380	13400	5730	3.90	1020	18.60	3.40	2.80	3.40				
GW-02	v	<.1	<.05	<.02	<.1	5510	13400	5570	2.60	15.0	8.30	40.90	330.00	40.90				
GW-02	vi	<.1	<.05	<.02	<.1	6060	13600	6260	3.70	66.0	4.80	45.20	480.00	45.20	0.30	7.84	64.90	
GW-02	vii	<.1	<.05	<.02	<.1	5290	13400	5410	3.60	4.4	3.50	33.10	315.00	33.10	0.30	3.38	37.50	
GW-02	viii	<.1	<.05	<.02	<.1	5070			3.60									
GW-04	a	<.1	<.05	<.02	<.1	4080	9910	3520	12.2	14.0	2.17	0.17	1.24	0.17				
GW-04	c	<.1	<.05	<.02	<.1	2010	6890	2260	14.8	450	4.00	0.12	2.24	0.12				
GW-04	e	<.1	<.05	<.02	<.1	2350	2550	2150	12.2	200	3.38	0.07	2.47	0.07				
GW-04	f	<.1	<.05	<.02	<.1	2680	7890	2810	5.10	51.0	3.06	0.02	2.02	0.02	0.25	0.12	1.30	
GW-05	a	<.1	<.05	<.02	<.1	9850	17000	9440	20.0	17.0	1.54	0.02	1.61	0.02				
GW-05	a	<1	<.5	N/T	<.5	10200	N/T	N/T	15.2/15.1	19.5	.31+-.04	N/A	.021+-.011	N/A				200
GW-05	b	<.1	<.05	<.02	<.1	363	11200	818	.30	3.3	0.25	0.05	0.18	0.05	0.25	<0.01	0.28	
GW-05	c	<.1	<.05	<.02	<.1	6270	12600	6680	14.2	79.0	2.45	0.26	0.07	0.26				
GW-05	d	<.1	<.05	<.02	<.1	10400	19600	12300	24.3	195	4.38	0.07	0.10	0.07				
GW-05	e	<.1	<.05	<.02	<.1	8320	16800	9000	23.1	120	4.42	0.07	0.53	0.07				
GW-05	f	<.1	<.05	<.02	<.1	6870	15400	7420	19.4	90	3.91	<.01	0.89	<.01				
GW-05	h	<.1	<.05	<.02	<.1	3060	3430	2970	2.95	38.0	2.72	<.01	0.82	<.01				
GW-05	i	<.1	<.05	<.02	<.1	4570	11400	4520	4.60									
GW-05	j	<.1	<.05	<.02	<.1	5940	12800	5930	2.80									
GW-05	k	<.1	<.05	<.02	<.1	2940	2290	2220	2.40	11.0	3.39	0.13	1.00	0.13				
GW-05	l	<.1	<.05	<.02	<.1	671	17300	622	.50	92	1.45	0.75	7.23	0.75				
GW-06	b	<.1	<.05	<.02	<.1	24.0	98.0	30.9	<.05	1.8	0.06	<.01	0.16	<.01				
GW-06	c																	
GW-07	b	<.1	<.05	<.02	<.1	6.90	98.0	10.4	<.05	1.5	0.06	0.07	0.07	0.07	<.05	0.03	0.72	
GW-07	d	<.1	<.05	<.02	<.1	163	343	164	<.05	1.5	<.01	0.03	0.15	0.03				
GW-07	f	<.1	<.05	<.02	<.1	39.7	213	43.2	<.05	3.7	0.04	0.05	0.10	0.05				
GW-07	f	<.1	<.02	N/T	<.05	46/49	N/T	N/T	0.13	<.5	.022+-.011	<.005	<.005	<.005				57
GW-08	a	<.1	<.05	<.02	<.1	20.4	20.0	19.9	<.05	4.0	0.04	0.05	0.12	0.05				

Table 1.11 - POREWATER - PHYSICAL, CHEMICAL AND RADIOLOGICAL ANALYSIS RESULTS FOR AUGUST SAMPLES

SITE	PIEZO-METER	TIP MATERIAL	DEPTH (m)	TEMP (°C)	DO (ppm)	pH	E.C.@25 C (uS/cm)	Fe 2+ (ppm)	ACIDITY (ppm CaCO3)	Ag (mg/L)	Al (mg/L)	As (ug/L)	B (mg/L)	Ba (mg/L)	Be (mg/L)	Ca (mg/L)	Cd (mg/L)	Co (mg/L)	Cr (mg/L)	Cu (mg/L)
GW-01	b	R	11.84	8.5	0.9	5.6	9000	12060	5960	<.005	<.01	2	.775	.024	<.0005	414	<.01	<.05	.01	.040
GW-01	f	T	1.24	13.5	1.2	2.1	5300	1340	1650	<.005	24.9	167	.044	.011	.0009	517	.01	.45	.02	.040
GW-02	a	ST	16.11			5.2	6000													
GW-02	b	T	14.48			5.0	10500													
GW-02	c	T	10.36	7.0	0.7	2.9	5300	5310	3000	<.005	52.2	2	.360	.011	.0315	436	.04	5.51	.24	.188
GW-02	d	T	2.60			<2.0	6400													
GW-02	e	T	1.02			<2.0	4200													
GW-02	i	T	7.90			3.6	6200													
GW-02	iii	T	6.60	7.0	0.65	3.6	5700	5140	4500	<.005	323	19	.366	.010	.0143	412	.02	1.64	.14	.037
GW-02	iv	T	5.51			3.4	5800													
GW-02	v	T	3.58	9.0	0.80	<2.0	14000	4580	5200	<.005	104	4	<.004	.006	.0040	437	.01	1.85	.23	.033
GW-02	vi	T	4.60			<2.0	11000													
GW-02	vii	T	2.62	11.5	1.3	<2.0	14000	4750	4950	<.005	100	125	<.004	.011	.0037	447	.01	1.70	.17	.056
GW-02	viii	T	1.48			<2.0	12000													
GW-03	b	T	10.52	6.5	0.65	6.85	4500	391	250	<.005	<.01	5	.649	.018	<.0005	471	.01	<.05	.02	<.008
GW-03	d	T	7.67	6.5	0.5	6.60	5300	838	500	<.005	<.01	7	.565	.011	<.0005	472	<.01	<.05	<.01	<.008
GW-03	e	T	6.12	6.2	0.6	6.50	4200													
GW-03	f	T	4.62	6.5	0.45	6.05	4850	1620	1150	<.005	<.01	1	.708	.017	<.0005	442	.02	<.05	<.01	.010
GW-03	f	DUPLICATE								.02	.38	2/4	.89	.03	<.01	450	.075	.07	.04	.010
GW-03	g	T	3.05	9.0	1.0	6.20	5200	1560	1200	<.005	<.01	2	.695	.022	<.0005	442	.02	<.05	<.01	.014
GW-04	a	ST	11.89	6.5	0.65	5.0	9000	4410	2550	<.005	<.01	<1	.217	.052	<.0005	421	.03	.41	<.01	.027
GW-05	a	ST	18.34			5.80	9400													
GW-05	b	R	28.42			6.20	3300													
GW-05	c	ST	22.10	6.5	0.6	5.80	7650	9830	4850	<.005	<.01	<1	.240	.020	<.0005	413	.01	.15	<.01	.038
GW-05	d	T	10.90			5.95	12000													
GW-05	e	T	9.24	7.0	0.6	5.95	10000	15800	8900	<.005	<.01	1	.825	.016	<.0005	403	.03	<.05	<.01	.068
GW-05	e	DUPLICATE								.04	.34	3	1.43/1.4	<.01	<.01	340	.61	.16	.06	.020
GW-05	f	T	7.95	6.5	0.5	6.00	7400	11280	6100	<.005	<.01	2	.404	.019	<.0005	400	.04	<.05	<.01	.052
GW-05	h	T	6.07	7.2	0.6	6.20	4000	3300	1800	<.005	<.01	1	.304	.013	<.0005	454	.02	<.05	<.01	.021
GW-05	i	T	4.32	7.5	0.5	5.80	7400	4180	2100	<.005	<.01	2	.151	.010	<.0005	426	.02	<.05	.02	.021
GW-05	j	T	2.79			3.00	6000													

Table 1.11 - POREWATER - PHYSICAL, CHEMICAL AND RADIOLOGICAL ANALYSIS RESULTS FOR AUGUST SAMPLES - Page Two

SITE	PIEZO-METER	Fe (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Mo (mg/L)	Na (mg/L)	Ni (mg/L)	P (mg/L)	Pb (mg/L)	Se (ug/L)	Si (mg/L)	Sr (mg/L)	Th (mg/L)	Ti (mg/L)	V (mg/L)	Zn (mg/L)	Zr (mg/L)
GW-01	b	3440	93	178	21.0	7.4	135	<.05	<.5	<.05	<1	5.63	1.36	<.05	.013	.126	.45	<.05
GW-01	f	345	8	15.2	1.17	.7	2	.48	.9	1.60	<1	61.9	.478	.34	.921	.043	.91	<.05
GW-02	a																	
GW-02	b																	
GW-02	c	1460	54	90.6	1.98	9.3	2	.73	<.5	<.05	<1	21.8	.497	5.90	2.40	.361	6.55	6.23
GW-02	d																	
GW-02	e																	
GW-02	i																	
GW-02	iii	1380	55	61.0	.55	3.8	3	1.00	<.5	.40	<1	40.3	.548	.95	.109	.464	.70	.22
GW-02	iv																	
GW-02	v	1370	59	32.4	.35	2.5	15	1.06	2.5	.95	2	68.0	.353	8.40	4.58	.198	.49	.11
GW-02	vi																	
GW-02	vii	1390	54	33.9	.33	3.0	14	1.27	3.3	.80	<1	72.9	.410	5.10	4.36	.170	6.30	.15
GW-02	viii																	
GW-03	b	101	62	453	9.09	.4	99	.08	.6	<.05	<1	6.90	1.08	<.05	<.005	.207	1.16	<.05
GW-03	d	201	88	454	10.4	.5	208	<.05	<.5	<.05	<1	6.85	.943	<.05	<.005	.172	.62	<.05
GW-03	e																	
GW-03	f	307	85	379	11.5	.8	128	<.05	<.5	<.05	<1	7.05	.707	<.05	<.005	.209	.34	<.05
GW-03	f	340	76	420	13.3	.09	128	.04	0.1	0.36	<.5	12.8	0.82	N/T	0.25	0.03	0.42	.31/.30
GW-03	g	353	89	346	9.41	.8	181	.05	<.5	<.05	<1	7.61	.651	.11	<.005	.209	.45	<.05
GW-04	a	1360	63	175	20.0	3.2	82	.08	<.5	<.05	<1	11.6	.953	.15	<.005	.118	.24	<.05
GW-05	a																	
GW-05	b																	
GW-05	c	2700	71	222	18.0	4.7	54	<.05	<.5	<.05	<1	9.41	1.22	<.05	<.005	.158	.19	<.05
GW-05	d																	
GW-05	e	4370	16	132	4.29	10.7	8	<.05	<.5	<.05	<1	12.9	.976	.11	.008	.114	.57	<.05
GW-05	e	4100	24	130	4.0	.34	23	.09	.2/.2	1.23	<.5	25/23	0.88	N/T	.31/.34	0.09	0.47	1.41
GW-05	f	3030	37	79.4	3.13	6.7	7	<.05	<.5	<.05	<1	11.9	1.15	.13	.009	.102	1.33	<.05
GW-05	h	970	45	98.0	6.03	1.4	21	<.05	<.5	<.05	<1	9.11	.728	.09	<.005	.100	.58	<.05
GW-05	i	1150	42	385	12.6	1.9	18	<.05	<.5	<.05	<1	10.6	.583	<.05	<.005	.180	.62	<.05

Table 1.11 - POREWATER - PHYSICAL, CHEMICAL AND RADIOLOGICAL ANALYSIS RESULTS FOR AUGUST SAMPLES - Page Three

SITE	PIEZO-METER	F^- (mg/L)	Cl^- (mg/L)	PO_4^{3-} (mg/L)	NO_3^- (mg/L)	NO_2^- (mg/L)	Br^- (mg/L)	SO_4^{2-} (mg/L)	$SO_4^{2-}(S_4)$ (mg/L)	NH_3-N (mg/L)	U (ppb)	Ra-226 (Bq/L)	Th-228 (Bq/L)	Th-230 (Bq/L)	Th-232 (Bq/L)
GW-01	b	5.32	13.2	<1	<5	<.2	<.5	7960	8300	17.3	4.4	1.49	0.05	0.25	0.05
GW-01	f	1.83	3.50	<1	<5	<.2	<.5	2320	2450	1.00	108.0	2.71	0.86	5.26	0.86
GW-02	a														
GW-02	b														
GW-02	c	50.6	7.30	<1	<5	<.2	<.5	4230	4400	2.67	26500	24.30	0.09	15.20	0.09
GW-02	d														
GW-02	d														
GW-02	i														
GW-02	iii	<.05	7.50	<1	<5	<.2	.5	5270	5490	1.54	2900	14.50	0.54	7.40	0.54
GW-02	iv														
GW-02	v	<.05	21.2	<1	<5	<.2	.5	5530	5790	3.22	9.6	11.10	37.80	350.00	37.80
GW-02	vi														
GW-02	vii	<.05	19.2	<1	<5	<.2	.5	5440	5790	1.17	6.0	4.16	18.90	176.00	18.90
GW-02	viii														
GW-03	b	3.39	69.9	<1	<5	<.2	<.5	2880	2880	14.0	400	3.66	0.12	1.40	0.12
GW-03	d	4.23	172	<1	<5	<.2	<.5	3100	3100	11.7	660	4.58	0.05	1.15	0.05
GW-03	e														
GW-03	f	3.44	86.8	<1	<5	<.2	<.5	3400	3270	11.7	110	4.76	0.03	1.00	0.03
GW-03	f	1.9	95	<1	<.5	N/T	<.5	3400	N/T	13.3	170	6.9 +-.3	.06 +-.01	.02 +-.01	<.01
GW-03	g	3.24	117	<1	<5	<.2	<.5	3320	3360	3.81	26	5.10	0.05	1.84	0.05
GW-04	a	2.45	44.6	<1	<5	<.2	<.5	4270	4310	11.7	40	2.60	0.09	0.82	0.09
GW-05	a														
GW-05	b														
GW-05	c	4.59	34.3	<1	<5	<.2	1.0	6830	6700	13.0	60	2.49	0.13	0.13	0.13
GW-05	d														
GW-05	e	6.32	4.99	<1	<5	<.2	2.0	9210	9130	20.8	60	4.55	0.09	1.32	0.09
GW-05	e	1.9	8.4	<1	<1	N/T	<5	9000	N/T	21	170	3 +-.2	.14 +-.01	.05 +-.01	<.01
GW-05	f	4.59	1.59	<1	<5	<.2	2.0	6740	6870	13.3	54	4.29	.13	1.40	.13
GW-05	h	3.03	17.5	<1	<5	<.2	<.5	3100	3100	1.84	34	4.10	0.09	1.48	0.09
GW-05	i	3.60	19.5	<1	<5	<.2	<.5	4440	4310	2.22	72	3.67	0.06	1.15	0.06

titanium, vanadium, zinc, zirconium), major anions (fluoride, chloride, phosphate, nitrate, nitrite, bromide, sulphate), ammonia, reduced sulphur, and radiological elements (uranium, radium-226, radium-228, thorium-228, thorium-232, polonium-210, lead-210). As was the case for the analyses of tailings solids, the primary and duplicate analyses of the major cations, metals and anions in the porewater and groundwater were performed by Barringer Magenta and Beak respectively. The primary and check laboratories for the radiological parameters were Chemex and Monenco respectively.

1.5.5 Sampling Methodology

Prior to the collection of the porewater and groundwater samples, standing water was purged from the piezometers using a peristaltic pump and downhole tube to ensure that the water collected during sampling represented fresh water. It was possible to pump several of the piezometers dry. For these piezometers, the sample was collected on the same day as purging after there had been sufficient recharge of water to the piezometers. For the piezometers that could not be pumped dry using the peristaltic pump, three piezometer volumes of water were removed during the purging process.

Two methods were used to collect the water samples. For the samples for the measurement of field parameters and for the analyses of major cations, metals and anions, a downhole syringe sampler was used. The larger sample volumes for the radiological analyses were obtained using a peristaltic pump.

A typical syringe sampler consists of a modified 50 mL plastic syringe (Feenstra et al, 1985). The syringe sampler was fitted with a plastic 25 mm filter holder and 0.45 um filter membrane. The sampler was connected to a dedicated length of polyethylene tubing using a one-holed rubber stopper and was lowered down the piezometer to the level of the piezometer intake. A vacuum pump was used to actuate the syringe plunger and draw water through the filter into the syringe. The syringe sampler was then removed from the piezometer and immediately capped with a sleeve serum stopper to prevent exposure of the sample to the atmosphere. Preservatives, if required, were added directly through the serum stopper using a 1 mL plastic syringe.

The modification to the sample syringe included the cutting of the plastic plunger just above the tip, and the trimming of the wings so that the syringe could fit down the piezometer. These modified syringes were washed with a 10 per cent solution of hydrochloric acid and rinsed several times with distilled water. The syringes were then individually wrapped in plastic bags and stored for use in the field.

For the radiological samples, the peristaltic pump was connected directly to a downhole length of polyethylene tubing. Each piezometer that was sampled had a dedicated length of polyethylene tubing to minimize the potential for cross-contamination between piezometers. A 142 mm filter holder with 0.45 um filter membrane was connected to the pump discharge to filter the samples.

The various parameters to be analyzed required that different sampling and handling procedures be used. These procedures are outlined below.

i) Electrical conductance and pH were measured using a combination pH and conductance meter (Myron L pDS Meter, Model EP-10/pH). The instrument was calibrated at the beginning of each day using pH 7 and pH 4 buffer. Between each reading, the accuracy of the instrument was checked using the pH 7 buffer.

   The measurement was made using a 50 mL unfiltered aliquot which was collected using a syringe sampler. The first 30 mL of the aliquot was used to rinse the sample chamber of the instrument. The final 20 mL was used for the sample analysis. This meter internally calibrated the conductivity readings to 25°C.

   For the June sampling, the pH and conductance in 13 piezometers at monitoring sites GW-02 and GW-05 (a and b), were measured using the Corning combination Meter 610A and the YSI Model 33 Temperature, Conductivity and Salinity Meter, respectively. For these readings, water was pumped to the surface using a peristaltic pump. As with the Myron meter, the Corning meter was calibrated using the two buffers at the beginning of each day and checked between sample measurements with the pH 7 buffer. Electrical conductance readings were standardized to 25°C.

The use of the Corning and YSI meters was discontinued after 13 of the sample measurements in June because of electrical problems in internal components of the Corning meter. Subsequently the Myron meter was used for both pH and conductivity measurements.

ii) Eh was to be measured using the Corning Meter 610A with an Eh electrode. However, problems were encountered in the field during June with calibration of the meter and electrode, unstable readings, and electrical failure of the meter. Because of the above, Eh measurements were discontinued during June and were not made in August; however, Eh conditions can be estimated using relationships between ferrous and ferric iron concentrations if it is assumed that the ferric iron concentration represents the difference between those for total and ferrous iron.

iii) Ferrous iron and acidity were measured by titration in the CAIRS office laboratory. The procedures used for the titrations are presented in Appendix 5.

Samples were collected using the syringe samplers and stored under refrigerated conditions until titrations were performed. Two 50 mL syringes from each piezometer were delivered to the CAIRS field laboratory, where one member of the sampling crew performed the analyses immediately following delivery. To facilitate sampling efficiency, samples from several piezometers were collected prior to each trip to the laboratory. Generally three sets of samples were delivered to the laboratory each day.

iv) A 50 mL syringe sample was collected for anion analyses (IC scan). This sample was filtered down-hole and kept refrigerated until the sample was delivered to the appropriate analytical laboratory.

v) A 50 mL syringe sample was collected for the analyses of major cations and metals. This sample was filtered down-hole, preserved with about 0.2 mL of concentrated HNO_3, and kept refrigerated until sample delivery to the analytical laboratory.

vii) Two 50 mL syringe samples were collected for the analysis of dissolved reduced sulphur. Both syringes were filtered down-hole. One of the syringes was preserved with about 0.1 mL of 50 per cent HCl and the other with about the same amount of 5 per cent H_2O_2. The samples were refrigerated until they were delivered to the analytical laboratory.

For the June sampling, problems were encountered with the analyses of reduced sulphur. Due to the very high concentrations of sulphate and the low concentrations of reduced sulphur species, the determination of reduced sulphur as the difference between the concentrations of the total sulphur and sulphate was unreliable.

viii) Two litres of sample were collected in two plastic sample bottles for radionuclide analysis. The samples were collected using the peristaltic pump, filtered in the field, and acidified with about 2 mL of concentrated HNO_3 for preservation.

ix) Temperature and dissolved oxygen were measured down-hole using a YSI Model 57 Temperature and Dissolved Oxygen Meter. Measurements were made after the other water samples had been collected. This ensured that contaminants from other piezometers were not introduced to a piezometer by the downhole probe prior to the collection of water samples for chemical analysis.

1.5.6 Sampling Results

The chemical results of the June and August porewater sampling programs are presented in Table 1.10 and Table 1.11 respectively.

Two monitoring stations, GW-02 (where the tailings were predominantly sandy) and GW-05 (where the tailings consisted of interlayered fine and coarse tailings), were monitored in detail; most of the monitoring points at the two stations were sampled. This allowed a detailed profile of the chemical composition of the porewater with depth at these two sites to be established. At the other stations, a few selected monitoring points were sampled.

Although detailed assessment and interpretation of the chemical results of the porewater/groundwater sampling program is not part of the scope of this study, some general features of the porewater chemistry in the Lacnor tailings are apparent. As has been found at other pyritiferous uranium tailings basins in the Elliot Lake area, the porewater chemistry in the Lacnor tailings has been influenced both by the chemistry of the initial mill discharge and pyrite oxidation at shallow depths in the tailings since their deposition. The porewater was characterized by high electrical conductivity values and elevated concentrations of iron, sulphate and calcium. Low pH conditions existed in some areas of the tailings but moderately acidic to neutral porewater was also present. The groundwater in the sub-tailings overburden and, to a lesser extent, sub-tailings bedrock piezometers exhibited similar chemical characteristics to the tailings porewater with the exception of radionuclides, which occurred at much lower concentrations; however, the impacts of the tailings on the groundwater chemistry in the bedrock piezometers at the off-tailings monitoring stations were generally low.

In coarse tailings in the western sections of the basin at monitoring stations GW-01 and GW-02, the pH levels of the porewater were less than 2 at shallow depths but increased to between 3 and 6 at depths of more than 5m in both the June and August monitoring periods. At monitoring station GW-02 the electrical conductance was higher in the shallow zone; it decreased from in excess of 10,000 µS/cm in the upper 5m to in the order of 5,000 µS/cm in the porewater at depths of more than 5m below ground surface.

In the eastern sections of the tailings at monitoring stations GW-03, GW-04 and GW-05, where interlayered fine and coarse tailings were present, the pH of the shallow porewater was not as low as that in the western sections and the trend of increasing pH with depth was less marked. The water table occurred at shallow depths at these monitoring stations and, during the spring and early summer of 1985, a large portion of the eastern part of the tailings basin was submerged beneath ponded water. The presence of the ponded water disrupted the trend of decreasing pH with depth in the June monitoring period. Also, possibly as a consequence of the pond, there was no general trend of elevated electrical conductance values at shallow depths with decreased values at increased depths in the porewater in these areas of the tailings.

The trends in the concentrations of the anions, cations and metals in the porewater with depth were less regular than the pH distributions. The iron and sulphate concentrations in the porewater were high across the tailings; iron concentrations ranged from several hundred to as much as 5,000 ppm and sulphate concentrations of as high as 10,000 ppm were present. The concentrations of iron and sulphate were typically higher at monitoring station GW-05 than at monitoring station GW-02 and did not appear to be directly related to the distribution of pH in the porewater. Although there were problems associated with the field titrations of ferrous iron in the August sampling period, the data indicated that the total iron consisted primarily of ferrous iron. Acidity levels in the porewater, expressed as calcium carbonate, were typically in the range of several hundred to 10,000 ppm and were directly related to the concentrations of ferrous iron.

The concentrations of anions other than sulphate were much lower than the sulphate concentrations in the porewater. Chloride concentrations ranged from less than 2 to as much as 175 ppm, but were generally much less than 100 ppm. Fluoride concentrations were typically less than 100 ppm in the tailings porewater. The concentrations of bromide, phosphate and nitrate were less than several ppm.

The concentration of calcium in the tailings porewater and sub-tailings groundwater ranged generally from 300 to 500 ppm and was independent of pH levels. Sodium, potassium and magnesium were present at concentrations ranging from less than 10 to as much as several hundred ppm. Aluminum occurred at concentrations ranging from less than 0.01 to as much as 400 ppm; the highest concentrations generally were present in porewater with pH levels of less than 4.

The concentrations of other metals were variable in the tailings porewater, but their peak concentrations were, in some cases, associated with low pH porewater. Manganese occurred at concentrations ranging from less than 1 to as much as 25 ppm. Zinc was generally present at concentrations of less than 10 ppm but did occur at a maximum concentration of 50 ppm. Cobalt, nickel and chromium generally occurred at concentrations below 1 ppm, but concentrations of several ppm were encountered in some porewater samples from monitoring station GW-02. Lead and selenium were generally present at concentrations of less than 1 ppm, but peak concentrations of several ppm were encountered. Arsenic concentrations ranged from less than 0.001 to 0.8 ppm. Cadmium and copper concentrations in the tailings porewater were less than 0.2 ppm.

At monitoring station GW-02, the distributions of concentrations of the radiological parameters in porewater exhibited some depth dependent trends. Uranium concentrations were less than 100 ppb at depths of less than 5 m below ground surface and increased to several thousand ppb at depths between 5.5 and 15 m below ground surface; a peak concentration of 9800 ppb was present in the porewater at a depth of approximately 15 m below ground surface. Radium-226 concentrations in the porewater also increased with depth ranging from less than 10 Bq/L at shallow depths to between 15 and 40 Bq/L at depths of more than 5.5 m. The opposite trend was present for thorium-230; concentrations decreased from between 300 and 500 Bq/L within 5 m of ground surface to less than 20 Bq/L below this depth. Thorium-228 and thorium-232 concentrations in the porewater followed profiles similar to that of thorium-230, but their concentrations were generally of the order of 10 per cent or less of the thorium-230 concentrations. Concentration of lead-210 ranged from less than 1 to more than 60 Bq/L. Polonium-210 occurred at concentrations of less than 10 Bq/L in the porewater at GW-02.

The concentrations of the radiological parameters in the groundwater in the sub-tailings sand and gravel were generally low. Uranium was present at 0.7 ppb, radium-226 at 3.35 Bq/L, thorium-230 at 4.1 Bq/L and concentrations of thorium-228, thorium-232, radium-228, polonium-210 and lead-210 were less than 0.3 Bq/L.

The distribution of radiological parameters in the porewater at monitoring station GW-05 differed from that at monitoring station GW-02. With the exception of uranium which occurred at concentrations of less than 20 ppb within 5 m of ground surface and as much as 200 ppb below this depth, the distributions of the concentrations of radiological parameters in tailings porewater were not depth dependent. In addition, the concentrations of the radiological parameters at monitoring station GW-05 were much lower than those at monitoring station GW-02. For example, concentrations of uranium and thorium-230 were less than 200 ppb and 2 Bq/L respectively, whereas the maximum concentrations of these parameters in the porewater at monitoring station GW-02 were 9800 ppb and 480 Bq/L respectively.

The tailings porewater had little or no impact on the groundwater chemistry at the off-tailings monitoring sites. The pH of the groundwater ranged from 5.5 to 7.5 and the electrical conductance ranged from 210 to 450 µS/cm. The concentrations of the major ions and metals, including iron and sulphate, and the radiological parameters in the bedrock groundwater at monitoring stations GW-06 and GW-07 were much lower than those encountered in the tailings porewater.

In addition to the tailings porewater, sub-tailings groundwater and off-tailings groundwater samples, two surface water samples were also collected during the June sampling period. Samples were obtained from the ponded water on the surface of the tailings near monitoring station GW-05 and from Dumbell Lake, the source of water used during the drilling of the sub-tailings and off-tailings boreholes.

The ponded surface water at monitoring station GW-05 was acidic and had a pH of 2.7. The electrical conductance was 1800 µS/cm. The iron and sulphate concentrations were approximately 70 and 670 ppm respectively. The concentrations of these parameters and those of most major ions and metals were lower than those typically encountered in the tailings porewater at monitoring station GW-05. For the radiological parameters, uranium and thorium-230 concentrations in the pond water were 92 ppb and 7.23 Bq/L respectively. Concentrations of radium-226, thorium-228 and thorium-232 were of the order of 1 Bq/L.

The chemical quality of the water from Dumbell Lake was generally good. The pH of the water was 8.1. The electrical conductance and concentrations of the major ions and metals of the water were low. The concentrations of uranium and thorium-230 in the lake water were 4 ppb and 0.12 Bq/L respectively. The concentrations of radium-236, thorium-228 and thorium-232 were less than 0.5 Bq/L.

1.5.7. Quality Assurance/Quality Control

The sampling methods and quality assurance protocols practised during the collection of the tailings porewater, subtailings groundwater and off-tailings groundwater samples were discussed previously in Section 1.5.6. Some of the precautionary measures taken to minimize the potential for the introduction of spurious contamination to the samples and to maintain sample integrity are summarized below.

The length of polyethylene tubing used to purge the piezometers and to collect water samples with the peristaltic pump and as a vacuum line for the syring samplers was dedicated to one piezometer. This eliminated the possibility of the transfer of contaminants between piezometers on the sampling tubing.

The sample bottles and syringes were obtained from commercial scientific and medical equipment supply companies and were used only once. The syringes, after the modifications to the wings and plunger had been made, were soaked in dilute acid and rinsed in a distilled water bath. The syringes were then wrapped in plastic for transport to the field. The plastic was not removed until sampling was to be performed.

The filters used during the collection of the syringe samples were attached directly to the syringe. Filtering was performed down-hole as the sample was collected. New filters were used for each piezometer.

The only pieces of equipment that contacted the water from more than one piezometer were the silicon tubing of the peristaltic pump and the filter holder for the 142 mm filters used during the collection of the samples for the radiological analyses only. The peristaltic pump was flushed with distilled water and with water from the piezometer being sampled prior to the actual collection of a water sample. The filter holder was soaked in a dilute acid bath and rinsed with distilled water prior to its use for the collection of each sample. A new filter disk was also used for each sample.

The acid used to preserve samples following their collection in the field was reagent grade and was obtained from a commercial chemical supply company. The acid was administered using a 1 mL syringe and needle. To minimize the contact between the water sample and air, the samples were acidified directly through the rubber serum stoppers used to cap the syringes.

All samples were refrigerated following their collection in the field until they could be delivered to the commercial laboratories for analysis.

The quality assurance/quality control program included the submission of duplicate samples to the primary and check laboratories. In addition, two blank samples of distilled water were collected in syringes and bottles using the standard sampling techniques used during the study for the analyses of major ions, metals and radiological parameters. As was the case for the tailings solids analyses, the primary laboratories for the analyses of major ions and metals was Barringer Magenta and for the radiological analyses was Chemex. The check laboratories were Beak and Monenco. The quality control protocols practiced by each of the laboratories are described in detail in Appendix 5.

A total of six duplicate water samples were submitted during the study, four during the June and two during the August sampling periods. For the samples for which primary and duplicate analyses were performed, the portions for the analyses of particular parameters were collected consecutively. Although some variability might exist in the chemical compositions of consecutive samples from the same piezometer, it is unlikely that the variability would be significant.

There was some variability in the porewater chemistry data received from the primary and check laboratories. Although the concentrations of the major constituents in the tailings porewater were broadly similar in the primary and duplicate analyses, the analytical results for some of the trace constituents in the porewater varied between the primary and check laboratories.

As was noted in the discussions on the tailings solid chemistry (Section 1.3.7 and 1.3.8), the cations and metals in the water samples were analysed using ICAP emission spectroscopy by Barringer Magenta and using DCP emission spectroscopy by Beak. Each scanning method is affected by different interferences and has different sensitivities to individual parameters; thus, some discrepancy between the results obtained by the two methods could be expected, especially for parameters that were present at concentrations similar to their detection limits by either method. The variability of the analytical results was further accentuated due to the fact that the water samples typically contained high concentrations of total dissolved solids and had to be diluted for the optimal sensitivity of the methods to some parameters to be obtained. Because of the dilutions, the minimum detection limits of the analytical methods were increased.

The analysis of sulphate in the tailings porewater proved to be a problem. In the samples that were simply refrigerated and in those that were treated with hydrogen peroxide and refrigerated following collection, a precipitate formed in many of the samples during the period of storage prior to the analyses. This occurred even though the samples had been filtered during the collection process. The precipitate likely consisted of sulphate and oxyhydroxide minerals. Thus, the analytical results for these samples were probably low. The samples that were acidified with hydrochloric acid remained free of precipitate minerals and yielded higher sulphate results. These concentrations were probably representative of the actual concentrations. Comparison of the analyses on the filtered and hydrogen peroxide-treated samples indicated that the concentrations of reduced sulphur in the water samples was low; however, because of the occurrence of precipitates in the samples, precise concentrations of reduced sulphur in the water samples could not be established.

There were also some discrepancies in the analytical results of the analyses of the radiological parameters in the tailings porewater. The concentrations of radium-226 and thorium-230 were lower in the analyses performed by Monenco than those performed by Chemex. Chemex employed an ion exchange column to remove some of the dissolved solids such as iron from the water samples prior to the radiological analyses. This procedure was not performed by Monenco, so it is possible that the high concentrations of dissolved solids created interferences and resulted in the lower analytical results for radium-226 and thorium-230. Both laboratories, however, assumed that their results were correct. Uranium concentrations were similar in the primary and duplicate analyses. The thorium-228 and 230 concentrations determined by Chemex for the June and August porewater samples were reported to be equal (see Tables 1.10 and 1.11). Subsequent to follow-up discussions these results were verified by the laboratory.

The results of the analyses of the blank water samples indicated that trace quantities of some of the major ions, heavy metals and radionuclides were detected in the distilled water samples. Based on the sampling procedures described above, the sources of cations and metals in the distilled water samples are not apparent. All syringes and filters were new and were used for one sample only. Aside from the acidification process, there was no apparent mechanism to introduce trace constituents to the blank water samples. The reported occurrences of the trace levels of cations and metals may have resulted from analytical sources or may be actual concentrations present in the commercially obtained distilled water.

The analyses of the blank water samples also indicated the presence of sulphate. Although the ion chromatograph column is flushed between analyses, there is the potential for some "carry over" to occur within the column if concentrations of anions were high in the sample analysed previously. Thus, remnants of previous samples could have remained within the column for the analyses of the blank samples. The high chloride concentrations introduced to the syringes with the hydrochloric acid made dilution of the sample a necessity prior to the analysis of sulphate and other anions; thus, it is possible that with the degree of dilution required, the detection limits for sulphate within particular samples may have been increased considerably.

Trace levels of the radiological parameters were also found in the blank water samples. Although the sources of these results is not clear, it is possible that trace levels of radiological parameters could have desolved from the silicon tubing or filter holder during the sample collection process. The cleaning procedures for this equipment were described previously. The sample containers were new and were used for one sample only; thus, leaching from the containers to the samples was not likely to be a significant source of contamination. There is a possibility that the concentrations of radiological parameters indicated to be present in the blank samples were a result of analytical errors or limitations.

The data obtained from the field titrations for ferrous iron also was a cause of concern. During the June sampling period, the titrations indicated that the total iron present in the water samples existed primarily as ferrous iron. Although the titrations were conducted in the same manner in the June and August sampling periods, the calculated concentrations of ferrous iron from the August sampling period based on the field titrations were about 3.5 times larger than the total iron concentrations measured by the commercial laboratories. In the absence of other evidence, it is believed that the error arose from an incorrectly prepared titrant solution. As was indicated by the results of the June sampling period, it would be expected ferrous iron was the primary component of the total iron concentrations.

The measurement of Eh in the water samples was abandoned early in the June sampling period. Prior to the development of problems with the meter, the Eh readings in the water samples were subject to considerable drift and instability so an accurate reading was difficult to obtain. A possible cause of this problem was the high concentrations of ferrous iron in the water samples. It is recommended that Eh conditions in the tailings porewater be estimated on the basis of concentrations of the ferrous/ferric iron couple rather than on the available Eh readings.

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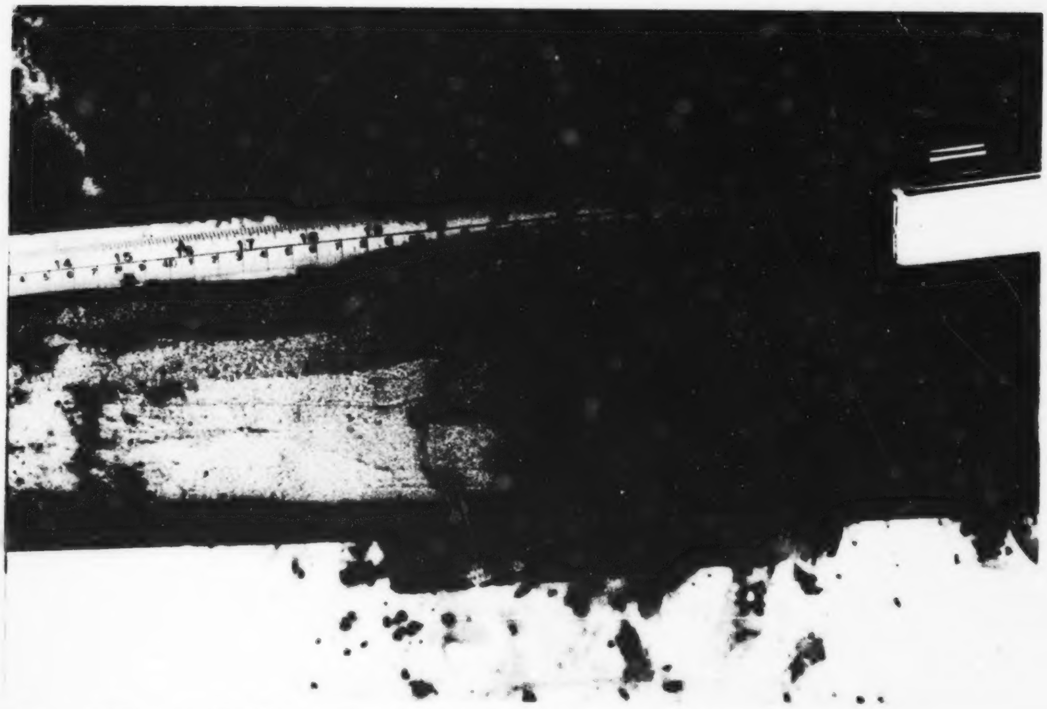
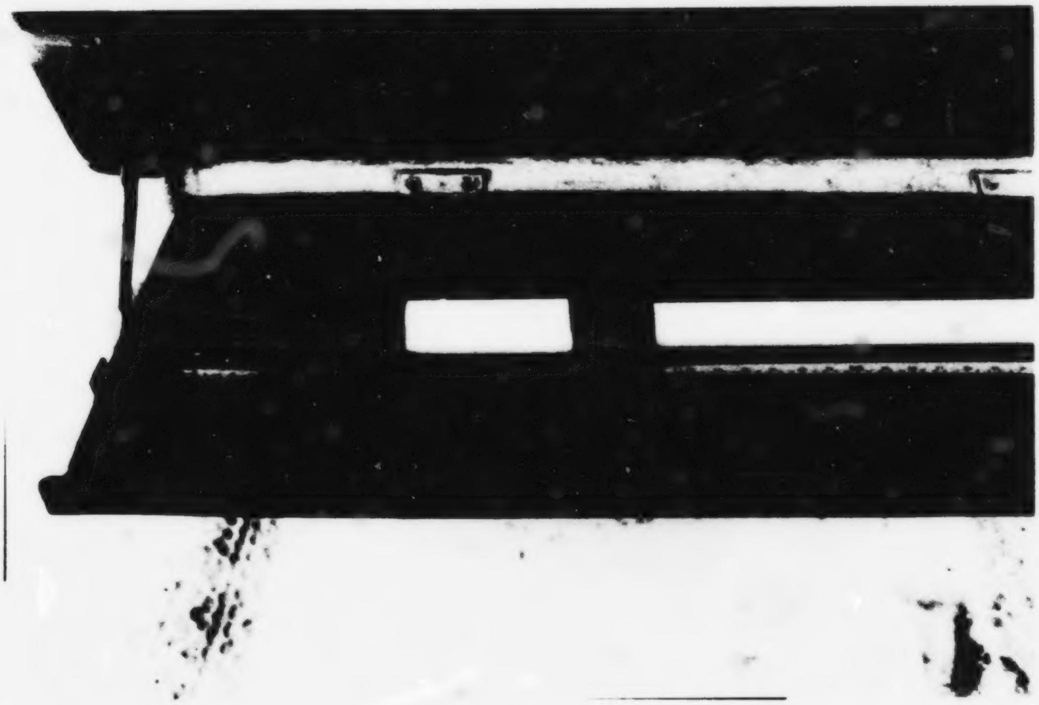
APPENDIX I.1

REPRESENTATIVE PHOTOGRAPHS

1. DRILLING OPERATIONS AT SITE SO-03



2. BROWN OXIDIZED AND GREY UNOXIDIZED SAND TAILINGS, SO-01a. INTERFACE AT 0.53 m BELOW GROUND SURFACE.



3. PIEZOMETER TIP FOR TAILINGS

4. PIEZOMETER INSTALLATION

5.   COMPLETED NEST OF PIEZOMETERS, SO-02

6.   POREWATER SAMPLING, SO-05, JUNE 1985

7. SO-06 SITE DURING DRILLING OPERATIONS

8. SO-07 SITE DURING HYDRAULIC CONDUCTIVITY TESTING

APPENDIX I.2

RECORD OF BOREHOLES

PROJECT 841-1934

SHEET 1 OF 2

RECORD OF BOREHOLES SO-1a,1b,1c,1d,1e AND 1f

LOCATION

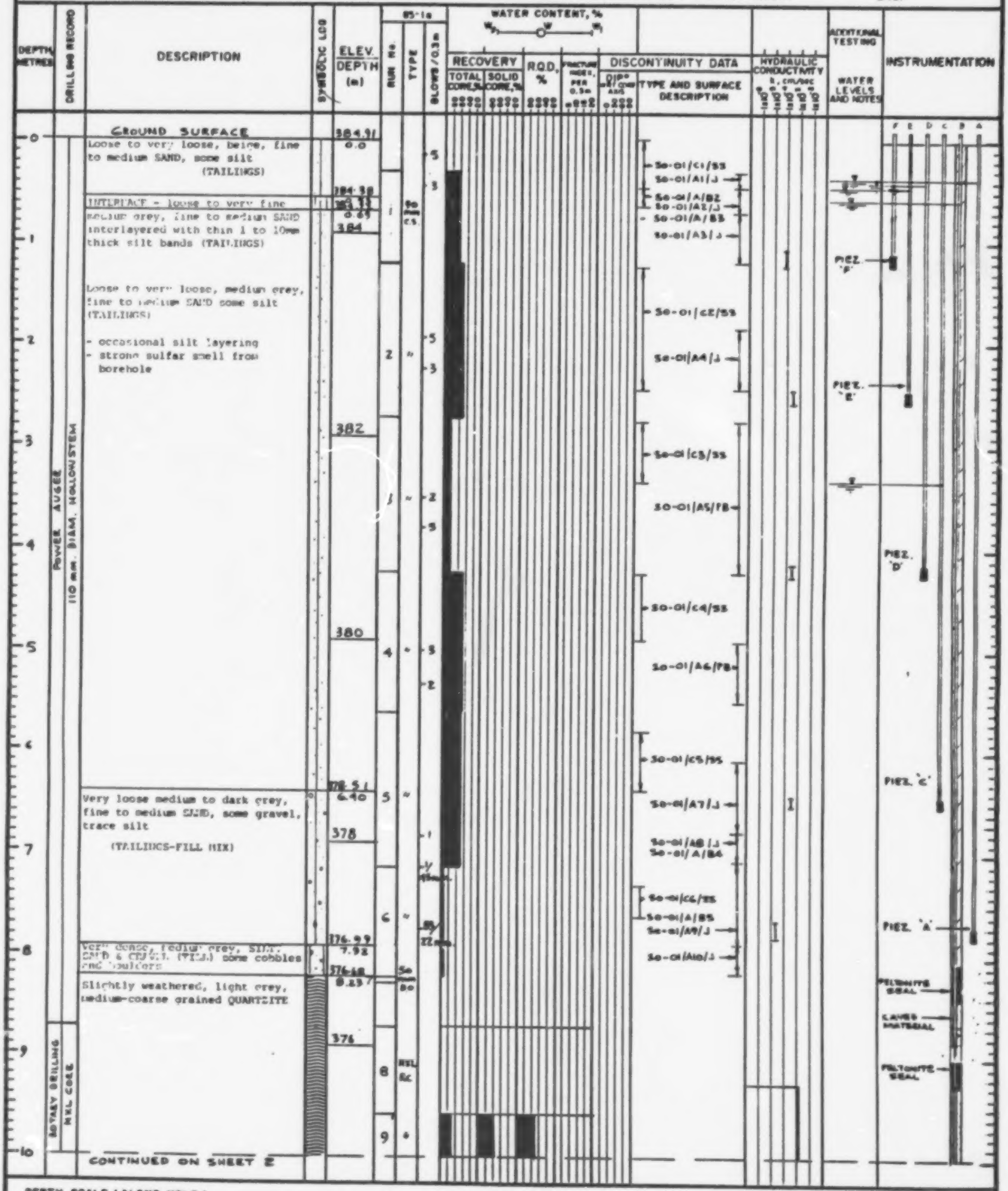
BORING DATE APRIL 1, 1985

DATUM

INCLINATION 90° AZIMUTH

SAMPLER / PENETRATION TEST HAMMER WEIGHT

DROP


DEPTH METRES
DRILLING RECORD
SYMBOLIC LOG
85-1a
WATER CONTENT, %
W_p — W — W_l
RECOVERY
TOTAL CORE, %
SOLID CORE, %
R.Q.D. %
FRACTURE INDEX PER 0.3m
DIP° W.R.T. CORE AXIS
HYDRAULIC CONDUCTIVITY k, cm/sec
ADDITIONAL TESTING
WATER LEVELS AND NOTES
INSTRUMENTATION
F E D C B A
PIEZ. 'F'
PIEZ. 'E'
PIEZ. 'D'
PIEZ. 'C'
PIEZ. 'A'
BENTONITE SEAL
CAVED MATERIAL
BENTONITE SEAL
0
1
2
3
4
5
6
7
8
9
10

DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No.	TYPE	BLOWS/0.3m
	GROUND SURFACE	384.91			
POWER AUGER 110 mm. DIAM. HOLLOWSTEM	Loose to very loose, beige, fine to medium SAND, some silt (TAILINGS)	0.0			5 3
	INTERFACE - loose to very fine medium grey, fine to medium SAND interlayered with thin 1 to 10mm thick silt bands (TAILINGS)	384.38 [illegible] 0.65 384	1	90 mm C.S.	
	Loose to very loose, medium grey, fine to medium SAND some silt (TAILINGS) - occasional silt layering - strong sulfar smell from borehole	382 380	2 3 4	" " "	5 3 2 5 3 2
	Very loose medium to dark grey, fine to medium SAND, some gravel, trace silt (TAILINGS-FILL MIX)	378.51 6.40 378	5 6	" "	1 1/15mm 85/22mm
	Very dense, medium grey, SILT. SAND & GRAVEL (TILL) some cobbles and boulders	376.99 7.92			
ROTARY DRILLING NXL CORE	Slightly weathered, light grey, medium-coarse grained QUARTZITE	376.68 8.23 376	8 9	So/Bo NXL Rc "	
	CONTINUED ON SHEET 2				

DISCONTINUITY DATA — TYPE AND SURFACE DESCRIPTION

- So-01/C1/SS
- So-01/A1/J
- So-01/A/B2
- So-01/A2/J
- So-01/A/B3
- So-01/A3/J
- So-01/C2/SS
- So-01/A4/J
- So-01/C3/SS
- So-01/A5/FB
- So-01/C4/SS
- So-01/A6/FB
- So-01/C5/SS
- So-01/A7/J
- So-01/A8/J
- So-01/A/B4
- So-01/C6/SS
- So-01/A/B5
- So-01/A9/J
- So-01/A10/J

DEPTH SCALE (ALONG HOLE)
1:50 METRIC

Golder Associates

ROCK LOGGED M.H. DRAWN D.M.
DATE APR. 12, 1985 CHECKED DA

FORM: GA-D-14 REDUCE TO 62.5% OF ORIGINAL SIZE [illegible]

PROJECT 841-1534

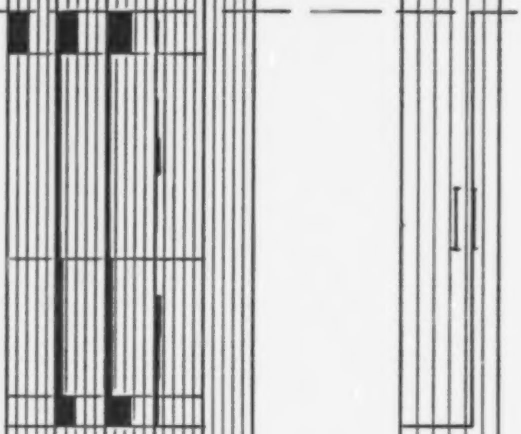
SHEET 2 OF 2

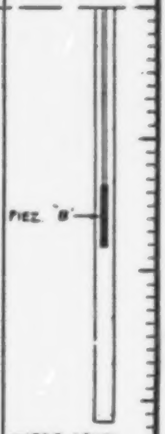
RECORD OF BOREHOLES SO-Ia,Ib,Ic,Id,IeANDIf (cont'd)

LOCATION
BORING DATE APRIL 1, 1985
DATUM
INCLINATION 90° AZIMUTH
SAMPLER / PENETRATION TEST HAMMER WEIGHT DROP

DEPTH METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	85-1A RUN No	85-1A TYPE	85-1A BLOWS / 0.3m
		CONTINUED FROM SHEET 1					
10	ROTARY DRILLING NXL CORE	- joints show penetrative weathering and staining up to 12 mm deep on most surfaces - traces of limonite on joint surfaces					
11				374	10	NXL RC	
12					11	"	
13				372	12	"	
		END OF HOLE		371.72 13.19			
14							
				370			

WATER CONTENT, % W_p — W — W_l | RECOVERY: TOTAL CORE, % · SOLID CORE, % | R.Q.D., % | FRACTURE INDEX PER 0.3m | DISCONTINUITY DATA: DIP° w.r.t. CORE AXIS · TYPE AND SURFACE DESCRIPTION | HYDRAULIC CONDUCTIVITY k, cm/sec | ADDITIONAL TESTING | WATER LEVELS AND NOTES | INSTRUMENTATION





WATER LEVEL IN PIEZOMETERS
1A - ELEV 384.42
1B - ELEV 384.27
1C - ELEV 384.58
1D - ELEV. 384.51
1E - ELEV. 384.55
1F - ELEV. 384.13
ON MAY 6, 1985

PIEZOMETER STICK UP ABOVE GROUND SURFACE
1A - 1.21 m.
1B - 1.20 m.
1C - 0.97 m.
1D - 0.27 m.
1E - 0.43 m.
1F - 0.24 m.

PIEZOMETER 1A, C, D, E AND F HAVE 12.7 cm. SCREENS
- 1B HAS 1m. SCREEN

DEPTH SCALE (ALONG HOLE)
1 : 50 METRIC

Golder Associates

ROCK LOGGED M.H. DRAWN D.M.
DATE APR. 12, 1985 CHECKED

FORM: GA-D-14 REDUCE TO 63 % OF ORIGINAL SIZE (XEROX 3400)

PROJECT 841-1334

SHEET 1 OF 2

RECORD OF BOREHOLES SO-2a,2b,2c,2d AND 2e

LOCATION

BORING DATE MARCH 28-29,1985

DATUM

INCLINATION 90° AZIMUTH —

SAMPLER / PENETRATION TEST HAMMER WEIGHT

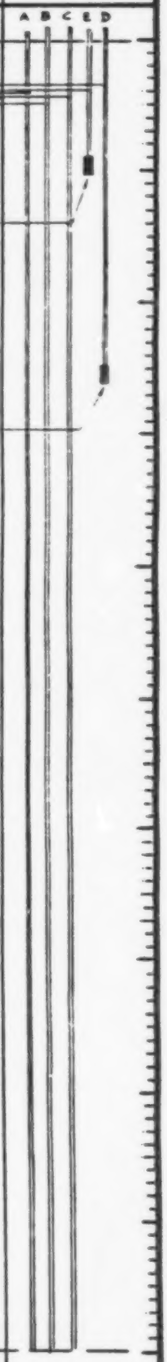
DROP

DRILLING RECORD: POWER AUGER 110 mm. DIAM. HOLLOW STEM

83-2A

DEPTH METRES	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	RUN No.	TYPE	BLOWS/0.3m	RECOVERY TOTAL CORE,%	RECOVERY SOLID CORE,%	R.Q.D. %	FRACTURE INDEX PER 0.3m	DISCONTINUITY DATA DIP° W.R.T. CORE AXIS	SAMPLES	HYDRAULIC CONDUCTIVITY k, cm/sec	ADDITIONAL TESTING / WATER LEVELS AND NOTES
	GROUND SURFACE		383.47											
0	Loose to very loose, beige to very light grey, fine to medium SAND, some SILT (TAILINGS)		0.0									So-02/A/B1 So-02/A1/J So-02/A/B2		
	Loose to very loose, light to medium grey, fine to medium SAND, some silt (TAILINGS)		382.96 0.46	1	90 mm CS							So-02/B1/SS SO-02/A2/J So-02/A/B3		
1	- silt as layers only to 5.8 m depth - strong sulfurous smell from borehole		382											PIEZ. "E"
2				2	"							So-02/D2/SS		
3			380	3	"							SO-02/A3/PS So-02/A4/J		PIEZ. "D"
4														
5			378	4	"									
6				5	"									
7			376									So-02/A5/J		
8				6	"							So-02/A6/PS So-02/A/B4		
9			374	7	"							So-02/A7/J		
10	CONTINUED ON SHEET 2													

INSTRUMENTATION



DEPTH SCALE (ALONG HOLE)
1:50 METRIC

Golder Associates

ROCK LOGGED M. H. DRAWN D.M.
DATE APRIL 15/85 CHECKED

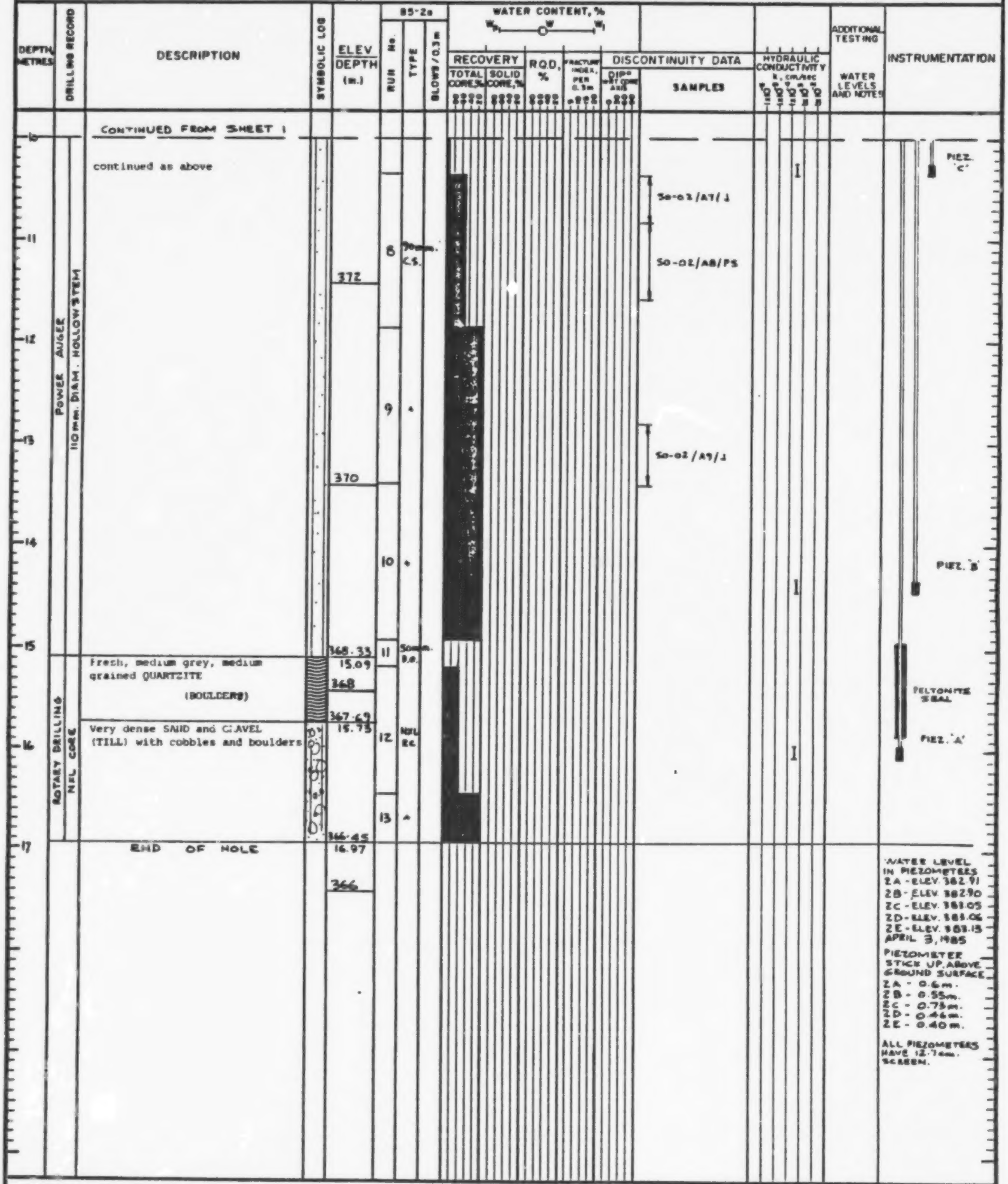
FORM: 8A-D-1d REDUCE TO 66% OF ORIGINAL SIZE (XEROX 2400)

PROJECT 841-1334

SHEET 2 OF 2

RECORD OF BOREHOLES SO-2a, 2b, 2c, 2d AND 2e cont'd

LOCATION
BORING DATE MARCH 23, 1985
DATUM
INCLINATION 90° AZIMUTH —
SAMPLER / PENETRATION TEST HAMMER WEIGHT
DROP


DEPTH METRES
DRILLING RECORD
DESCRIPTION
SYMBOLIC LOG
ELEV DEPTH (m.)
85-2a
RUN No.
TYPE
BLOWS / 0.3m
WATER CONTENT, %
Wp W Wl
RECOVERY
TOTAL CORE,%
SOLID CORE,%
R.Q.D., %
FRACTURE INDEX, PER 0.3m
DISCONTINUITY DATA
DIP° W.R.T. CORE AXIS
SAMPLES
HYDRAULIC CONDUCTIVITY k, cm/sec
ADDITIONAL TESTING
WATER LEVELS AND NOTES
INSTRUMENTATION
CONTINUED FROM SHEET 1
10
11
12
13
14
15
16
17
POWER AUGER
110mm. DIAM. HOLLOW STEM
ROTARY DRILLING
NQ CORE
372
370
368.33
15.09
368
367.69
15.75
366.45
16.97
366
8
90mm. C.S.
9
10
11
50mm. D.O.
12
NQ RC
13
SO-02/A7/J
SO-02/A8/PS
SO-02/A9/J
PIEZ. 'C'
PIEZ. 'B'
BENTONITE SEAL
PIEZ. 'A'

DESCRIPTION	ELEV / DEPTH (m.)
continued as above	368.33 15.09
Fresh, medium grey, medium grained QUARTZITE (BOULDERS)	367.69 15.75
Very dense SAND and GRAVEL (TILL) with cobbles and boulders	366.45 16.97
END OF HOLE	

WATER LEVEL IN PIEZOMETERS
2A - ELEV. 382.91
2B - ELEV. 382.90
2C - ELEV. 383.05
2D - ELEV. 383.06
2E - ELEV. 383.13
APRIL 3, 1985

PIEZOMETER STICK UP, ABOVE GROUND SURFACE
2A - 0.6m.
2B - 0.55m.
2C - 0.73m.
2D - 0.46m.
2E - 0.40m.

ALL PIEZOMETERS HAVE 12.7mm. SCREEN.

DEPTH SCALE (ALONG HOLE)
1:50 METRIC

Golder Associates

ROCK LOGGED M.H. DRAWN D.M.
DATE MAY 22, 1985 CHECKED

FORM: 9A-D-14

PROJECT 841-1334

SHEET 1 OF 2

RECORD OF BOREHOLES SO-3a,3b,3c,3d,3e,3f,3g&3h

LOCATION
BORING DATE MARCH 19, 1985
DATUM
INCLINATION
AZIMUTH
SAMPLER / PENETRATION TEST HAMMER WEIGHT
DROP

DRILLING RECORD: POWER AUGER, 110 mm. DIAM. HOLLOWSTEM

DEPTH METRES	DESCRIPTION	SYMBOLIC LOG	ELEV. / DEPTH (m)	85-3A RUN No.	TYPE	BLOWS/0.3m
0	GROUND SURFACE		379.61			
	Loose to very loose, light brown, fine to medium SAND, some silt (TAILINGS)		0.0 379.00	1	90mm C.S.	
	Loose to very loose, dark reddish fine to medium SAND, some silt (TAILINGS)		0.61 378.70			
1	Loose to very loose, dark grey, fine to medium SAND, some silt (TAILINGS)		0.91 378.24			
2	Loose to very loose, dark grey, SILT, some fine to medium SAND as layers (TAILINGS)		1.37 377.17	2	"	
3	Loose to very loose, dark grey SILT, some fine to medium SAND as layers		2.44	3	"	
4	(TAILINGS)		376 375.04	4	"	
5	Very loose, dark grey to black SILT, some fine to medium SAND		4.57	5	"	
6	(TAILINGS)		374 373.51			
7	Loose to very loose, dark grey interlayered SILTS and fine to medium SAND (TAILINGS) - occasional layers of light grey, fine to medium SAND		6.10	6	"	
8			372	7	"	
9			370 369.86	8	"	
10			9.75			

CONTINUED ON SHEET 2

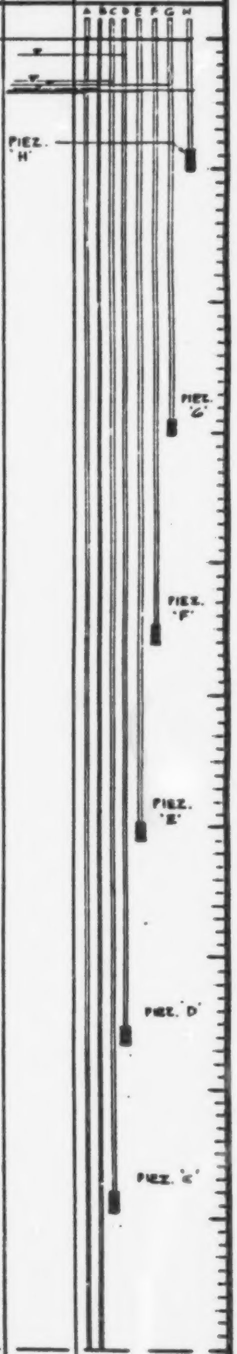
WATER CONTENT, %: W_p — W — W_l

RECOVERY: TOTAL CORE, % / SOLID CORE, % — R.Q.D., % — FRACTURE INDEX, PER 0.3m — DISCONTINUITY DATA: DIP° W.R.T. CORE AXIS

HYDRAULIC CONDUCTIVITY k, cm/sec

ADDITIONAL TESTING

SAMPLES
- So-03/A/B1
- So-03/A1/J
- So-03/A/B3
- So-03/A2/J
- So-03/A/B2
- So-03/B1/PS
- So-03/A3a/J
- So-03/A3b/J
- So-03/A4/J
- So-03/A5a/J
- So-03/B2/PS
- So-03/B3/PS
- So-03/A5b/J
- So-03/A/B3
- So-03/A6/J
- So-03/B4/PS
- So-03/B5/PS
- So-03/A7a/J
- So-03/A7b/J
- So-03/A8a/J
- So-03/B6/PS
- So-03/A8b/J



DEPTH SCALE (ALONG HOLE)
1:50 METRIC

Golder Associates

ROCK LOGGED M.H. DRAWN D.M.
DATE APRIL 15, 1985 CHECKED

FORM: G.A.-D-1d REDUCE TO 62% OF ORIGINAL SIZE (XEROX 2400)

PROJECT 841-1334

SHEET 2 OF 2

LOCATION

INCLINATION AZIMUTH

RECORD OF BOREHOLES SO-3a,3b,3c,3d,3e,3f,3g & 3h

BORING DATE MARCH 19, 1985 DATUM

SAMPLER / PENETRATION TEST HAMMER WEIGHT DROP

DEPTH METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	85-3A RUN No.	85-3A TYPE	85-3A BLOWS/0.3m	WATER CONTENT, % RECOVERY TOTAL CORE %	RECOVERY SOLID CORE %	R.Q.D. %	FRACTURE INDEX PER 0.3m	DISCONTINUITY DATA DIP° w.r.t. CORE AXIS	SAMPLES	HYDRAULIC CONDUCTIVITY k, cm/sec	ADDITIONAL TESTING WATER LEVELS AND NOTES	INSTRUMENTATION
10		CONTINUED FROM SHEET 1														
	POWER AUGER 110 mm. DIAM. HOLLOWSTEM	Loose to very loose, dark grey to black														PIEZ. 'B'
11		VERY DENSE, dark brownish grey, silty SAND and GRAVEL (TILL)		368.64 10.97	9	90mm C.S.							SO-03/A9/J			
				368	10	50mm. D.O.							SO-03/A10/J			
12																PIEZ. 'A'
				366.97	11	"							SO-03/A11/J			
		END OF HOLE Auger refusal		12.64												
13																WATER LEVEL IN PIEZOMETERS 3A - ELEV. 379.2 3B - ELEV. 379.23 3C - ELEV. 379.28 3D - ELEV. 377.23 3E - ELEV. 379.49 3F - ELEV. 379.21 3G - ELEV. 379.24 3H - ELEV. 379.21 ON JUNE 4, 1985
				366												
14																PIEZOMETER TUBE STICK UP (ABOVE GROUND SURFACE 3A - 0.58 m. 3B - 0.82 m. 3C - 0.85 m. 3D - 0.61 m. 3E - 0.67 m. 3F - 0.64 m. 3G - 0.76 m. 3H - 1.28 m.

DEPTH SCALE (ALONG HOLE)
1:50 METRIC

Golder Associates

ROCK LOGGED M.H. DRAWN D.M.
DATE APRIL 15/85 CHECKED GA

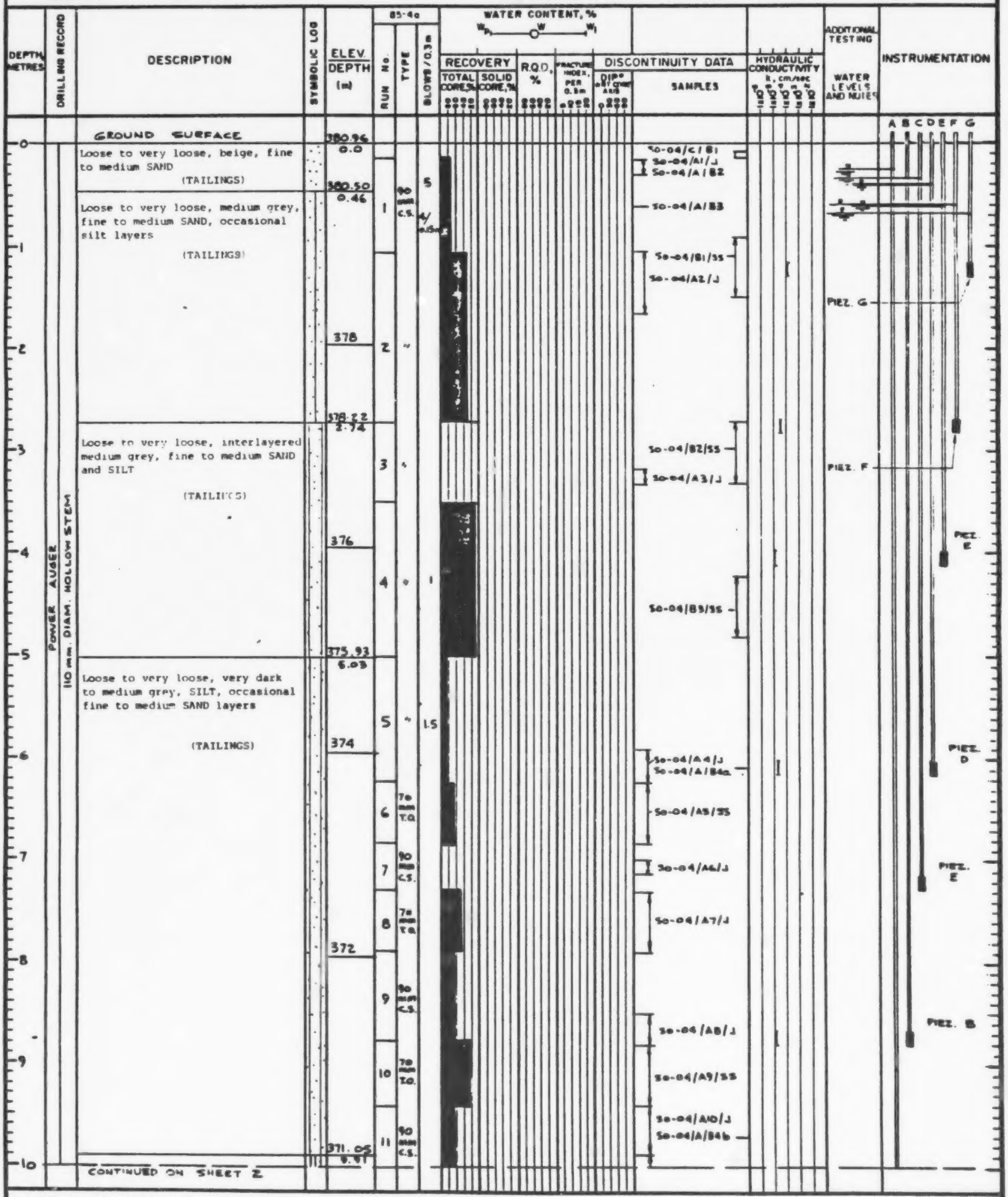
FORM: S.A.-D-14 REDUCE TO 62% OF ORIGINAL SIZE (XEROX 2400)

PROJECT 841-1334

SHEET 1 OF 2

RECORD OF BOREHOLES SO-4a,4b,4c,4d,4e,4f & 4g

LOCATION
BORING DATE MARCH 30 AND 31, 1985
DATUM
INCLINATION
AZIMUTH
SAMPLER / PENETRATION TEST HAMMER WEIGHT
DROP



DEPTH METRES	DRILLING RECORD	DESCRIPTION	ELEV. / DEPTH (m)	RUN No. (85-4a)	TYPE	BLOWS/0.3m
0		GROUND SURFACE	380.96			
	POWER AUGER 110 mm. DIAM. HOLLOW STEM	Loose to very loose, beige, fine to medium SAND (TAILINGS)	0.0			5
		Loose to very loose, medium grey, fine to medium SAND, occasional silt layers (TAILINGS)	380.50 0.46	1	90 mm C.S.	4/0.15m
2			378	2	"	
		Loose to very loose, interlayered medium grey, fine to medium SAND and SILT (TAILINGS)	378.22 2.74	3	"	
4			376	4	"	1
		Loose to very loose, very dark to medium grey, SILT, occasional fine to medium SAND layers (TAILINGS)	375.93 5.03	5	"	1.5
6			374	6	70 mm T.O.	
				7	90 mm C.S.	
				8	70 mm T.O.	
8			372	9	90 mm C.S.	
				10	70 mm T.O.	
10		CONTINUED ON SHEET 2	371.05 9.91	11	90 mm C.S.	

WATER CONTENT, %
W_p W W_l
RECOVERY
TOTAL CORE, %
SOLID CORE, %
R.Q.D. %
FRACTURE INDEX, PER 0.3m
DISCONTINUITY DATA
DIP° w.r.t. CORE AXIS
HYDRAULIC CONDUCTIVITY k, cm/sec
ADDITIONAL TESTING
WATER LEVELS AND NOTES
INSTRUMENTATION
SYMBOLIC LOG
A B C D E F G
PIEZ. G
PIEZ. F
PIEZ. E
PIEZ. D
PIEZ. E
PIEZ. B

SAMPLES
- So-04/C/B1
- So-04/A1/J
- So-04/A/B2
- So-04/A/B3
- So-04/B1/SS
- So-04/A2/J
- So-04/B2/SS
- So-04/A3/J
- So-04/B3/SS
- So-04/A4/J
- So-04/A/B4a
- So-04/A5/SS
- So-04/A6/J
- So-04/A7/J
- So-04/A8/J
- So-04/A9/SS
- So-04/A10/J
- So-04/A/B4b

DEPTH SCALE (ALONG HOLE)
1:50 METRIC

Golder Associates

ROCK LOGGED M.H. DRAWN D.M.
DATE APRIL 16, 1985 CHECKED JA

FORM: G.A.-O-14 REDUCE TO 64% OF ORIGINAL SIZE (XEROX 9400)

PROJECT 891-1534

SHEET 2 OF 2

LOCATION

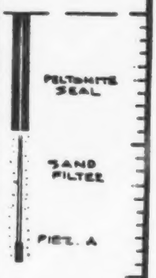
INCLINATION AZIMUTH

RECORD OF BOREHOLES SO-4a,4b,4c,4d,4e,4f &4g

BORING DATE MARCH 30 AND 31, 1985 DATUM

SAMPLER / PENETRATION TEST HAMMER WEIGHT DROP

DEPTH METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	85-4a RUN No.	TYPE	BLOWS / 0.3m	WATER CONTENT, % W_p — W — W_l RECOVERY TOTAL CORE, % / SOLID CORE, %	R.Q.D. %	FRACTURE INDEX, PER 0.3m	DISCONTINUITY DATA DIP° W.R.T. CORE AXIS	SAMPLES	HYDRAULIC CONDUCTIVITY k, cm/sec	ADDITIONAL TESTING WATER LEVELS AND NOTES	INSTRUMENTATION
		CONTINUED FROM SHEET 1													
10	POWER AUGER 110mm. DIAM. HOLLOWSTEM	Very dense, medium redcish brown silty SAND & GRAVEL (TILL) - 15 cm of black topsoil/humus at 9.91' - occasional cobbles and boulders			12							So-04/A11/J So-04/A/5a So-04/A/5b So-04/A12/J			PELTONITE SEAL SAND FILTER PIEZ. A
11				370											
12					13								I		
		END OF HOLE AUGER REFUSAL		368.64 12.32											
				368											
				366											



WATER LEVEL IN PIEZOMETERS
4A - ELEV. 380.7
4B - ELEV. 380.7
4C - ELEV. 380.58
4D - ELEV. 380.54
4E - ELEV. 380.48
4F - ELEV. 380.4
4G - ELEV. 380.31
MAY 6, 1985

PIEZOMETER TUBE STICK-UP
4A - 0.91 m.
4B - 0.39 m.
4C - 0.39 m.
4D - 0.61 m.
4E - 0.58 m.
4F - 0.39 m.
4G - 0.39 m.

ALL PIEZOMETERS HAVE A 12.7cm. SCREEN

BH. 85-4A WAS FLUSHED CLEAN PRIOR TO PIEZOMETER INSTALLATION.

DEPTH SCALE (ALONG HOLE)
1 : 50 METRIC

Golder Associates

ROCK LOGGED M.H DRAWN D.M.
DATE APRIL 16, 1985 CHECKED

FORM: G.A.-D-3d REDUCE TO 60 % OF ORIGINAL SIZE (XEROX 9400)

PROJECT 841-1534

SHEET 1 OF 4

RECORD OF BOREHOLES SO-5a,5b,5c,5d,5e,5f,5g,5h,5i,5j AND 5k

LOCATION
BORING DATE MARCH 22-24, 1985
DATUM
INCLINATION
AZIMUTH
SAMPLER / PENETRATION TEST HAMMER WEIGHT
DROP

DEPTH METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH	85-5a RUN No.	TYPE	BLOWS / 0.3m
0		GROUND SURFACE		379.89 0.0			
	POWER AUGER 110 mm. DIAM. HOLLOW STEM	ICE		379.59 0.3			
		Medium brown, silty SAND and GRAVEL (FILL)	▨	379.29 0.6			
		Loose to very loose, light grey, laminated fine to medium SAND (TAILINGS)		378.82 1.07	1	90 mm C.S.	
1–7		Loose to very loose, interlayered medium grey, SILT and fine to medium SAND (TAILINGS)		378 376 374 372.73 7.16	2 3 4 5	" " " "	
7–10		Loose to very loose, interlayered light and medium grey, fine to medium SAND and SILT (TAILINGS)		372 370	6 7	" "	
10		CONTINUED ON SHEET 2					

WATER CONTENT, % W_p —○ W— W_l

RECOVERY: TOTAL CORE %, SOLID CORE %; R.Q.D. %; FRACTURE INDEX, PER 0.3m; DISCONTINUITY DATA: DIP° W.R.T. CORE AXIS; SAMPLES

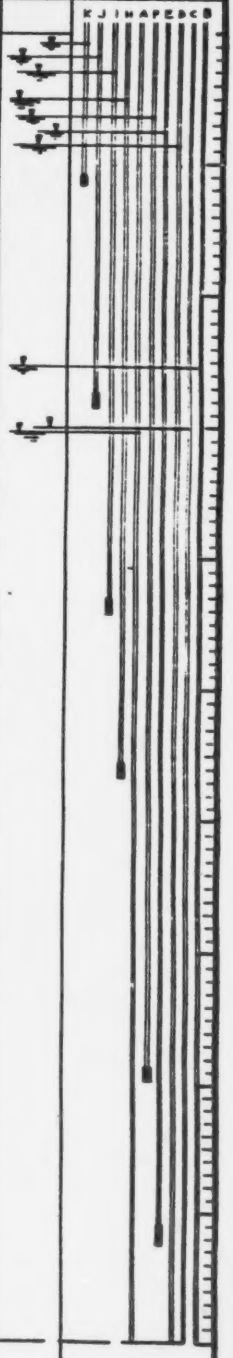
SAMPLES:
- SO-05/B/PB1
- SO-05/B1/J
- SO-05/B/B2
- SO-05/B/PB2
- SO-05/A1/PS
- SO-05/B/B2
- SO-05/B/PB3
- SO-05/B/PB4
- SO-05/B2/J
- SO-05/B3/J
- SO-05/B/PB5
- SO-05/B4/J
- SO-05/B/PB6
- SO-05/B/PB7
- SO-05/61/PS
- SO-05/B5/J
- SO-05/B/PB8
- SO-05/62/PS
- SO-05/B/PB9
- SO-05/63/PS
- SO-05/B/PB10
- SO-05/B6/J
- SO-05/B7/J
- SO-05/B/PB11
- SO-05/B/PB12

HYDRAULIC CONDUCTIVITY k, cm/sec

ADDITIONAL TESTING

WATER LEVELS AND NOTES

INSTRUMENTATION



DEPTH SCALE (ALONG HOLE)
1:50 METRIC

Golder Associates

ROCK LOGGED M.H.
DRAWN D.M.
DATE APRIL 16,1985
CHECKED

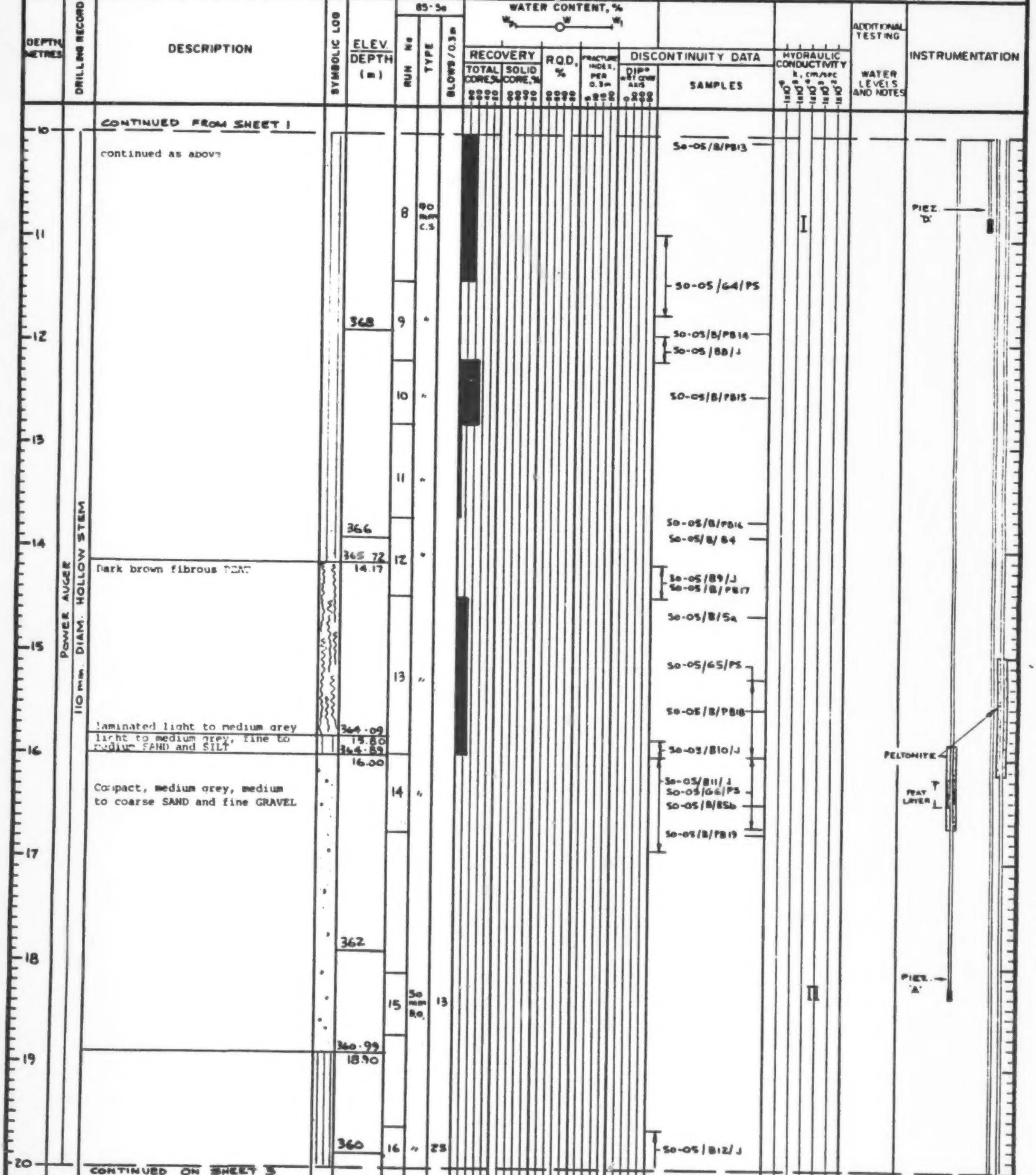
FORM: G.A.-D-1d REDUCE TO 66 % OF ORIGINAL SIZE (XEROX 2400)

PROJECT 841-1334

SHEET 2 OF 4

RECORD OF BOREHOLES SO-5a,5b,5c,5d,5e,5f,5g,5h,5i,5j,AND 5k (cont'd.)

LOCATION
BORING DATE MARCH 22-24, 1985
DATUM
INCLINATION
AZIMUTH
SAMPLER / PENETRATION TEST HAMMER WEIGHT
DROP



WATER CONTENT, %
W_p W W_l
RECOVERY
TOTAL CORE,%
SOLID CORE,%
R.Q.D. %
FRACTURE INDEX, PER 0.3m
DISCONTINUITY DATA
DIP° W.R.T. CORE AXIS
HYDRAULIC CONDUCTIVITY k, cm/sec
ADDITIONAL TESTING
WATER LEVELS AND NOTES
10
11
12
13
14
15
16
17
18
19
20
I
II

DEPTH METRES	DRILLING RECORD	DESCRIPTION	ELEV. DEPTH (m)	85-5a RUN No	TYPE	BLOWS/0.3m	SAMPLES	HYDRAULIC CONDUCTIVITY	INSTRUMENTATION
10	POWER AUGER 110 mm. DIAM. HOLLOW STEM	CONTINUED FROM SHEET 1 continued as above		8	90 mm C.S		So-05/B/PB13	I	PIEZ. 'D'
11							So-05/G4/PS		
12			368	9	"		So-05/B/PB14 So-05/B8/J		
13				10	"		So-05/B/PB15		
				11	"				
14			366				So-05/B/PB16 So-05/B/B4		
		Dark brown fibrous PEAT	365.72 14.17	12	"		So-05/B9/J So-05/B/PB17 So-05/B/5a		
15		laminated light to medium grey		13	"		So-05/G5/PS So-05/B/PB18		
		light to medium grey, fine to medium SAND and SILT	364·09 15.80						
16		Compact, medium grey, medium to coarse SAND and fine GRAVEL	364·89 16.00	14	"		So-05/B10/J So-05/B11/J So-05/G6/PS So-05/B/B5b So-05/B/PB19		PELTONITE PEAT LAYER
17									
18			362	15	50 mm Ro.	13		II	PIEZ. 'A'
19			360·99 18.90						
			360	16	"	25	So-05/B12/J		
20		CONTINUED ON SHEET 3							

DEPTH SCALE (ALONG HOLE)
1:50 METRIC

Golder Associates

ROCK LOGGED M.H. DRAWN D.M.
DATE APRIL 17, 1985 CHECKED

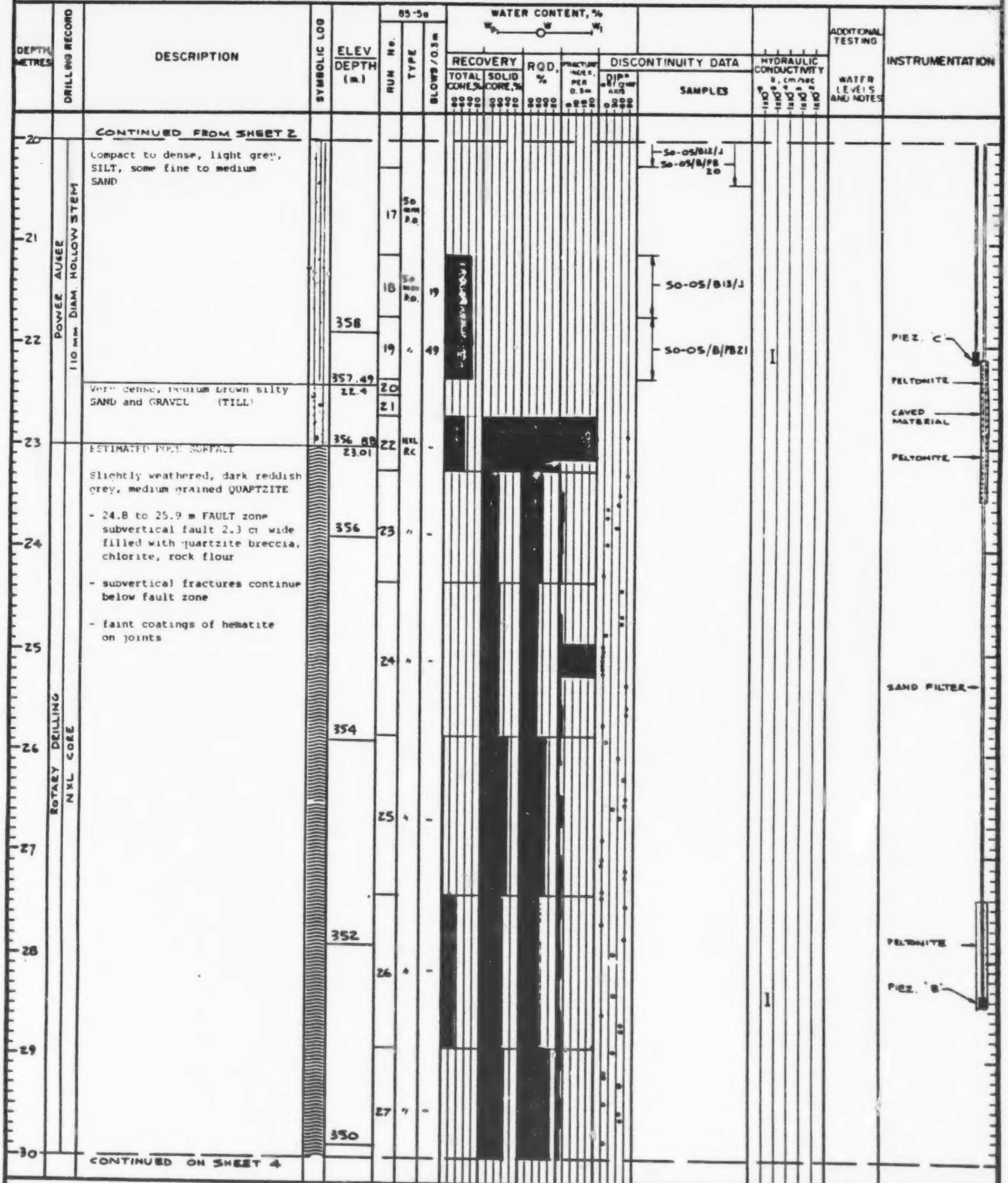
FORM: G.A.-D-1d REDUCE TO 64% OF ORIGINAL SIZE (XEROX 3400)

PROJECT 841-1334

SHEET 3 OF 4

RECORD OF BOREHOLES SO-5a,5b,5c,5d,5e,5f,5g,5h,5i,5j AND5k (cont'd)

LOCATION
BORING DATE MARCH 22 - 24, 1985
DATUM
INCLINATION
AZIMUTH
SAMPLER / PENETRATION TEST HAMMER WEIGHT
DROP


DEPTH METRES
DRILLING RECORD
SYMBOLIC LOG
85-5a
WATER CONTENT, %
Wp
W
Wl
RECOVERY
TOTAL CORE,%
SOLID CORE,%
RQD, %
FRACTURE INDEX, PER 0.3m
DISCONTINUITY DATA
DIP° w/r CORE AXIS
HYDRAULIC CONDUCTIVITY k, cm/sec
ADDITIONAL TESTING
WATER LEVELS AND NOTES
INSTRUMENTATION
20
21
22
23
24
25
26
27
28
29
30
POWER AUGER
110 mm DIAM. HOLLOW STEM
ROTARY DRILLING
NXL CORE
PIEZ. 'C'
PELTONITE
CAVED MATERIAL
PELTONITE
SAND FILTER
PELTONITE
PIEZ. 'B'

DEPTH METRES	DESCRIPTION	ELEV DEPTH (m)	RUN No.	TYPE	BLOWS/0.3m	SAMPLES
20	CONTINUED FROM SHEET 2					
	Compact to dense, light grey, SILT, some fine to medium SAND					So-05/B12/J So-05/B/PB 20
			17	50 mm D.O.		
			18	50 mm D.O.	19	SO-05/B13/J
		358	19	"	49	SO-05/B/PB21
	Very dense, medium brown silty SAND and GRAVEL (TILL)	357.49 22.4	20			
			21			
23	ESTIMATED ROCK SURFACE	356.88 23.01	22	NXL RC	-	
	Slightly weathered, dark reddish grey, medium grained QUARTZITE - 24.8 to 25.9 m FAULT zone subvertical fault 2.3 cm wide filled with quartzite breccia, chlorite, rock flour - subvertical fractures continue below fault zone - faint coatings of hematite on joints	356	23	"	-	
			24	"	-	
		354				
			25	"	-	
		352	26	"	-	
		350	27	"	-	
30	CONTINUED ON SHEET 4					

DEPTH SCALE (ALONG HOLE)
1:50 METRIC

Golder Associates

ROCK LOGGED M.H.
DRAWN D.M.
DATE APRIL 17, 1985
CHECKED

FORM: G.A.-D-1d REDUCE TO 66% OF ORIGINAL SIZE [illegible]

PROJECT 841-1334

SHEET 4 OF 4

RECORD OF BOREHOLES SO-5a,5b,5c,5d,5e,5f,5g,5h,5i,5j, AND 5k (cont'd)

LOCATION

BORING DATE MARCH 22-24, 1985

DATUM

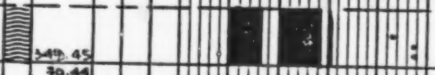
INCLINATION

AZIMUTH

SAMPLER / PENETRATION TEST HAMMER WEIGHT

DROP

DEPTH METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	85-5e RUN No	TYPE	BLOWS / 0.3m	WATER CONTENT, % RECOVERY TOTAL CORE, %	SOLID CORE, %	R.Q.D., %	FRACTURE INDEX, PER 0.3m	DISCONTINUITY DATA DIP° w.r.t. CORE AXIS	SAMPLES	HYDRAULIC CONDUCTIVITY k, cm/sec	ADDITIONAL TESTING WATER LEVELS AND NOTES	INSTRUMENTATION
		CONTINUED FROM SHEET 3														
30				349.45												
		END OF HOLE		30.44												
31																WATER LEVEL IN PIEZOMETERS 5A - ELEV. 376.64 5B - ELEV. 377.34 5C - ELEV. 376.85 5D - ELEV. 378.99 5E - ELEV. 379.16 5F - ELEV. 379.22 5G — 5H - ELEV. 379.4 5I - ELEV. 382.53 5J - ELEV. 382.69 5K - ELEV. 382.85 APRIL 3, 1985
				348												
32																PIEZOMETER TUBE STICK-UP ABOVE GROUND SURFACE 5A - 0.52 m. 5B - 0.43 m 5C - 0.64 m. 5D - 0.39 m 5E - 0.57 m 5F - 0.36 m 5G - NO INSTALLATION 5H - 0.64 m. 5I - 0.34 m. 5J - 0.34 m. 5K - 0.52 m. PIEZOMETERS 5a, 5c, 5d, 5e, 5f, 5h, 5i, 5j, 5k HAVE 12.7 cm. SCREENS 5b HAS A 1m. SCREEN.



DEPTH SCALE (ALONG HOLE)
1:50 METRIC

Golder Associates

ROCK LOGGED M.H. DRAWN D.M.
DATE APRIL 17/85 CHECKED

FORM: GA-D-1d REDUCE TO 50 % OF ORIGINAL SIZE [illegible]

PROJECT No. 841-1334

SUMMARY OF BOREHOLE SO-6a

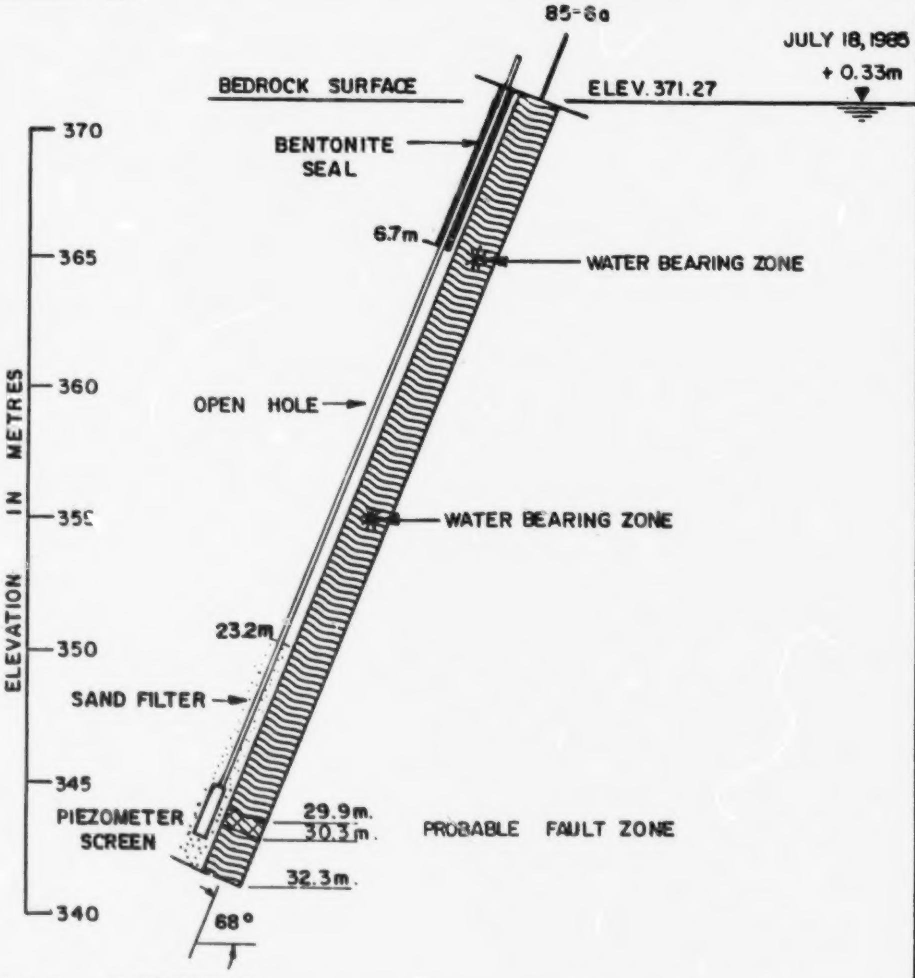
SHEET 1 OF 1

LOCATION OF HOLE	ADJACENT TO WEIR #1 SEE FIGURE

DATUM & LEVEL	**INCLINATION, AZIMUTH, ALONG HOLE LENGTH**	**CO-ORDINATES**
	68° E 32.34 m 106 ft. 1 in.	

TYPE OF DRILLING & MACHINE	**CORE BARREL & BIT DESIGN**	**DRILLING FLUID & FEED**	**DRILLING DATES**
GARDNER DENVER AIR TRACK	BUTTON BIT	AIR FLUSH HYDRAULIC FEED	STARTED JUNE 5/85 COMPLETED JUNE 5/85

SUMMARY LOG



85-6a
JULY 18, 1985
+ 0.33m
BEDROCK SURFACE
ELEV. 371.27
370
BENTONITE SEAL
6.7m
365
WATER BEARING ZONE
360
OPEN HOLE
355
WATER BEARING ZONE
ELEVATION IN METRES
23.2m
350
SAND FILTER
345
PIEZOMETER SCREEN
29.9m.
30.3m.
PROBABLE FAULT ZONE
32.3m.
340
68°

SCALE 1:250 METRIC

DATE LOGGED JUNE 5/85

DATE PHOTOGRAPHED N.A.

LOGGED BY M.W.H.

DRAWN BY D.M.

CHECKED BY M.W.H.

LEGEND

- ▤ UPPER MISSISSAGI FORMATION QUARTZITE
- ▨ NIPISSING DIABASE

REMARKS Hole collared and avanced entirely through quartzite.
Intersected small water bearing zones at 6.7 and 17.4 m depths.
Cuttings changed from light grey to light brown between 29.9 to 30.3 m

ALL DOWN HOLE DEPTHS, THICKNESSES AND ELEVATION IN METRES.

DRILLING CONTRACTOR	**CLIENT**
MATHEWS GROUP LTD.	NATIONAL URANIUM TAILINGS PROGRAM

Golder Associates

FORM: G.A.-D-1B

PROJECT No. 841-1334

SUMMARY OF BOREHOLE SO-6b

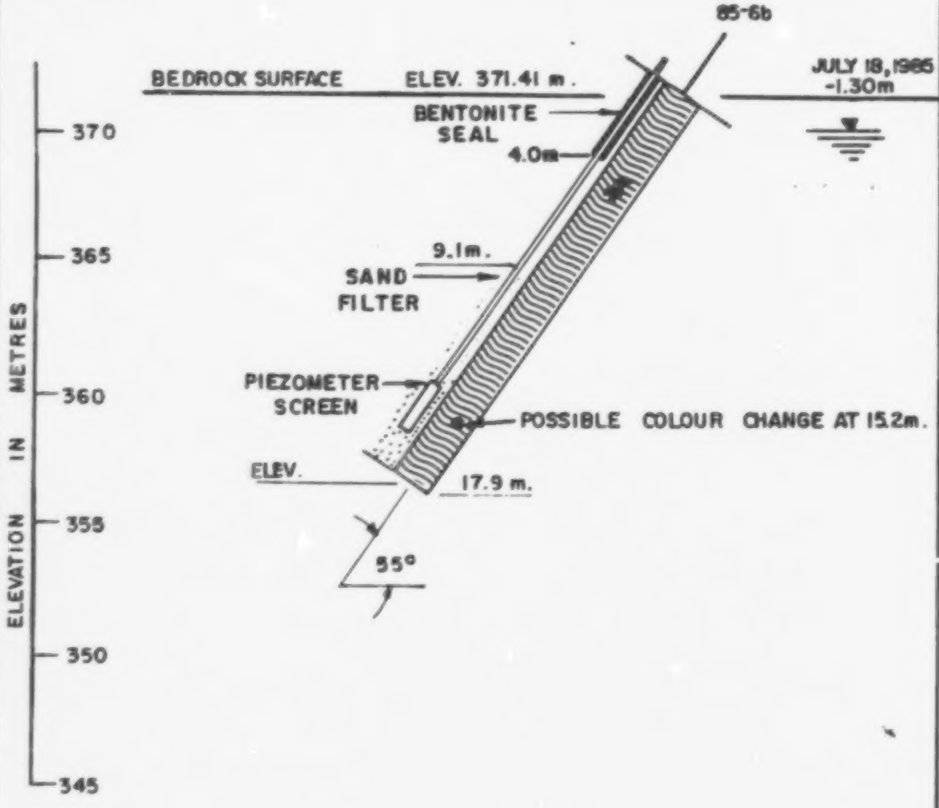
SHEET 1 OF 1

LOCATION OF HOLE ADJACENT TO WEIR #1
SEE FIGURE

DATUM & LEVEL	INCLINATION, AZIMUTH, ALONG HOLE LENGTH			CO-ORDINATES
	55°	E.	17.93 m. (58 ft. 10 in.)	

TYPE OF DRILLING & MACHINE	CORE BARREL & BIT DESIGN	DRILLING FLUID & FEED	DRILLING DATES
GARDNER DENVER AIR TRACK	BUTTON BIT	AIR FLUSH HYDRAULIC FEED	STARTED JUNE 5/85 COMPLETED JUNE 5/85

SUMMARY LOG


85-6b
BEDROCK SURFACE
ELEV. 371.41 m.
JULY 18, 1985
-1.30m
BENTONITE SEAL
4.0m
9.1m.
SAND FILTER
PIEZOMETER SCREEN
POSSIBLE COLOUR CHANGE AT 15.2m.
ELEV.
17.9 m.
55°
370
365
360
355
350
345
ELEVATION IN METRES

SCALE 1:250 METRIC

DATE LOGGED JUNE 5/85

DATE PHOTOGRAPHED N.A.

LOGGED BY M.W.H.

DRAWN BY D.M.

CHECKED BY M.W.H.

LEGEND

- ▤ UPPER MISSISSAGI FORMATION QUARTZITE
- ▨ NIPISSING DIABASE
- * WATER BEARING ZONE 4.0-4.6m

REMARKS Hole collared and advanced through quartzite.
Intersected water bearing zone between 4.0-4.6 m depths.
Hole very wet and muddy below that depth.

ALL DOWN HOLE DEPTHS, THICKNESSES AND ELEVATION IN METRES.

DRILLING CONTRACTOR	CLIENT
MATHEWS GROUP LTD.	NATIONAL URANIUM TAILINGS PROGRAM

Golder Associates

FORM: G.A.-D-1B

PROJECT No. 841-1334

SUMMARY OF BOREHOLE SO-6c

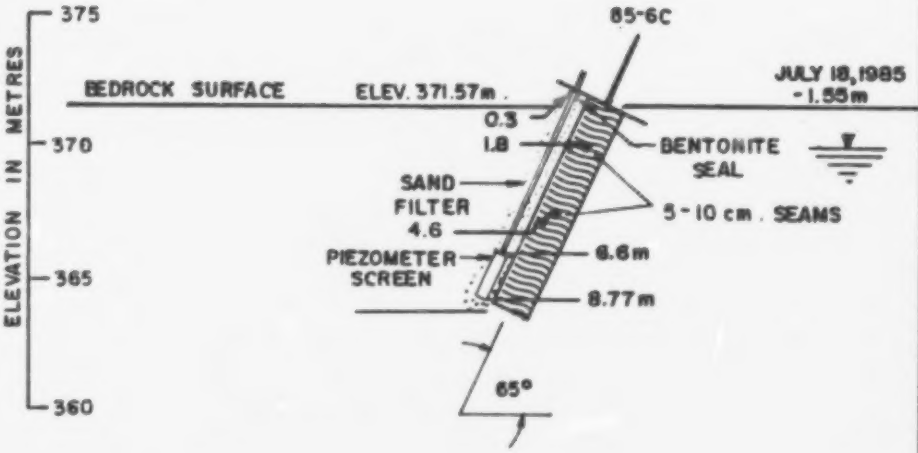
SHEET 1 OF 1

LOCATION OF HOLE	ADJACENT TO WEIR #1 SEE FIGURE

DATUM & LEVEL	**INCLINATION, AZIMUTH, ALONG HOLE LENGTH**	**CO-ORDINATES**
	65° EAST 8.77m. (28 ft. 9 in)	

TYPE OF DRILLING & MACHINE	**CORE BARREL & BIT DESIGN**	**DRILLING FLUID & FEED**	**DRILLING DATES**
GARDNER DENVER AIR TRACK	BUTTON BIT	AIR FLUSH HYDRAULIC FEED	STARTED JUNE 5/85 COMPLETED JUNE 5/85

SUMMARY LOG


375
370
365
360
ELEVATION IN METRES
85-6C
BEDROCK SURFACE
ELEV. 371.57m.
JULY 18, 1985
-1.55m
0.3
1.8
BENTONITE SEAL
SAND FILTER
5-10 cm. SEAMS
4.6
PIEZOMETER SCREEN
6.6m
8.77m
65°

SCALE SCALE 1:250 METRIC

DATE LOGGED JUNE 5/85

DATE PHOTOGRAPHED N.A.

LOGGED BY M.W.H.

DRAWN BY D.M.

CHECKED BY M.W.H.

LEGEND

▤	UPPER MISSISSAGI FORMATION QUARTZITE
▨	NIPISSING DIABASE

REMARKS Hole collared and advanced through quartzite.
Hole dry and dusty throughout drilling operations.

ALL DOWN HOLE DEPTHS, THICKNESSES AND ELEVATION IN METRES.

DRILLING CONTRACTOR	**CLIENT**
MATHEWS GROUP LTD.	NATIONAL URANIUM TAILINGS PROGRAM

Golder Associates

FORM: G.A.-D-1B

PROJECT No. 841-1334

SUMMARY OF BOREHOLE SO-7a

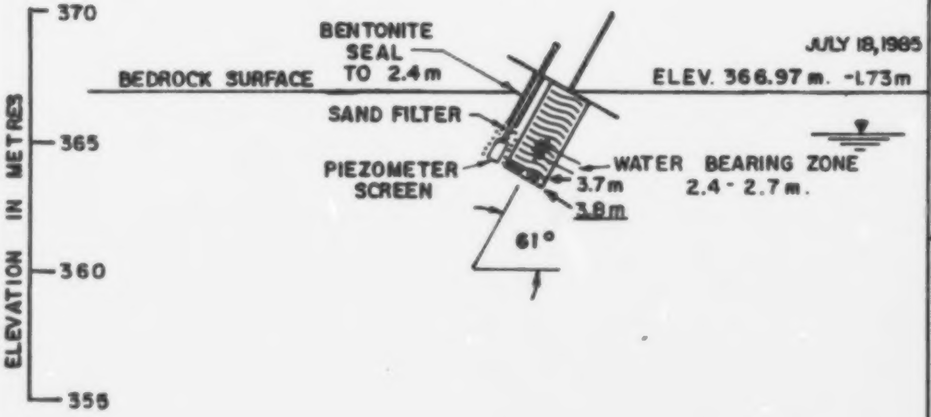
SHEET 1 OF 1

LOCATION OF HOLE Adjacent to weir #2
See Figure

DATUM & LEVEL	**INCLINATION, AZIMUTH, ALONG HOLE LENGTH** 61° N.E. 3.83 m. (12 ft. 7 in.)	**CO-ORDINATES**

TYPE OF DRILLING & MACHINE GARDNER DENVER AIR TRACK	**CORE BARREL & BIT DESIGN** BUTTON BIT	**DRILLING FLUID & FEED** AIR FLUSH HYDRAULIC FEED	**DRILLING DATES** **STARTED** June 7/85 **COMPLETED** June 7/85

SUMMARY LOG


370
365
360
355
ELEVATION IN METRES
BEDROCK SURFACE
BENTONITE SEAL TO 2.4 m
SAND FILTER
PIEZOMETER SCREEN
JULY 18, 1985
ELEV. 366.97 m. -1.73 m
WATER BEARING ZONE 2.4 - 2.7 m.
3.7 m
3.8 m
61°

SCALE 1:250 METRIC

DATE LOGGED June 7/85

DATE PHOTOGRAPHED N.A.

LOGGED BY M.W.H.

DRAWN BY D.M.

CHECKED BY M.W.H.

LEGEND

▤	UPPER MISSISSAGI FORMATION QUARTZITE
▨	NIPISSING DIABASE

REMARKS Borehole collared in quartzite which extends to 3.7 m depth. Diabase from 3.7 to 3.8 m. Intersected water bearing zone between 2.4 and 2.7 m depth. Hydraulic conductivity tests indicate 85-7a & 7c are interconnected.

ALL DOWN HOLE DEPTHS, THICKNESSES AND ELEVATION IN METRES.

DRILLING CONTRACTOR MATHEWS GROUP LTD.	**CLIENT** NATIONAL URANIUM TAILINGS PROGRAM

Golder Associates

FORM: G.A.-D-1B

PROJECT No.

SUMMARY OF BOREHOLE SO -7b

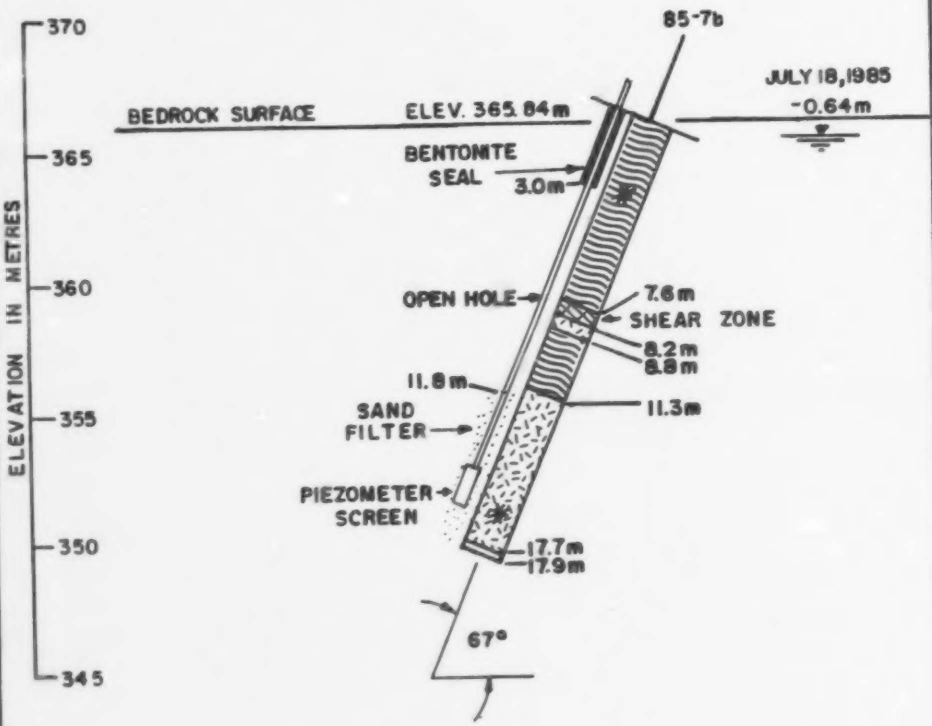
SHEET 1 OF 1

LOCATION OF HOLE Adjacent to Weir #2
See Figure

DATUM & LEVEL	INCLINATION, AZIMUTH, ALONG HOLE LENGTH			CO-ORDINATES
	67°	N.E.	17.9 m. (58ft. 9 in.)	

TYPE OF DRILLING & MACHINE	CORE BARREL & BIT DESIGN	DRILLING FLUID & FEED	DRILLING DATES
GARDNER DENVER AIR TRACK	BUTTON BIT	AIR FLUSH HYDRAULIC FEED	STARTED June 7/85 COMPLETED June 7/85

SUMMARY LOG



370
365
360
355
350
345
ELEVATION IN METRES
85-7b
BEDROCK SURFACE
ELEV. 365.84 m
JULY 18, 1985
-0.64 m
BENTONITE SEAL
3.0m
OPEN HOLE
7.6 m
SHEAR ZONE
8.2 m
8.8 m
11.8 m
11.3 m
SAND FILTER
PIEZOMETER SCREEN
17.7 m
17.9 m
67°

DATE LOGGED June 7/85

DATE PHOTOGRAPHED N.A.

LOGGED BY M.W.H.

DRAWN BY D.M.

CHECKED BY M.W.H.

LEGEND

▤ UPPER MISSISSAGI FORMATION QUARTZITE

▨ NIPISSING DIABASE

* WATER BEARING ZONE 16.2 m

SCALE 1:250 METRIC

REMARKS Borehole collared in quartzite which extends to 7.6 m. Heavy limonite/hematite oxidation zone of shear zone 7.6 to 8.2 m. Diabase 8.2 to 8.8 m. Quartzite 8.8 to 11.3m Diabase 11.3 to 17.7 m. Quartzite 17.7 to 17.9 m. Intersected moist zone at 3.0 and wet zone at 16.2 m.

ALL DOWN HOLE DEPTHS, THICKNESSES AND ELEVATION IN METRES

DRILLING CONTRACTOR	CLIENT
MATHEWS GROUP LTD.	NATIONAL URANIUM TAILINGS PROGRAM

Golder Associates

FORM: G.A.-D-1B

PROJECT No. 841-1334

SUMMARY OF BOREHOLE SO-7c

SHEET 1 OF 1

LOCATION OF HOLE: Adjacent to Weir #2
See Figure

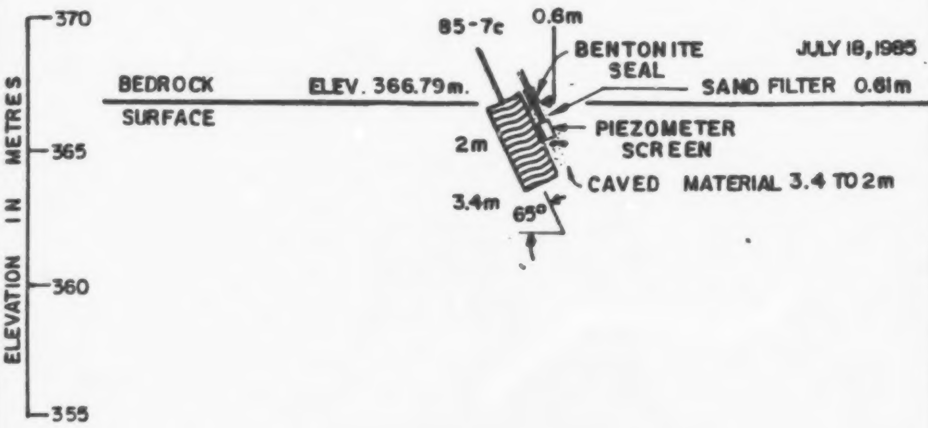
DATUM & LEVEL	INCLINATION, AZIMUTH, ALONG HOLE LENGTH	CO-ORDINATES
	65° S.W. 3.4 m. (11ft. 2in.)	

TYPE OF DRILLING & MACHINE	CORE BARREL & BIT DESIGN	DRILLING FLUID & FEED
GARDNER DENVER AIR TRACK	BUTTON BIT	AIR FLUSH HYDRAULIC FEED

DRILLING DATES
STARTED June 7/85
COMPLETED June 7/85

DATE LOGGED June 7/85
DATE PHOTOGRAPHED N.A.
LOGGED BY M.W.H.
DRAWN BY D.M.
CHECKED BY M.W.H.

SUMMARY LOG


ELEVATION IN METRES
370
365
360
355
BEDROCK
SURFACE
ELEV. 366.79m.
85-7c
0.6m
BENTONITE SEAL
JULY 18, 1985
SAND FILTER 0.61m
PIEZOMETER SCREEN
2m
CAVED MATERIAL 3.4 TO 2m
3.4m
65°

LEGEND

▤	UPPER MISSISSAGI FORMATION QUARTZITE
▨	NIPISSING DIABASE

SCALE 1:250 METRIC

REMARKS Borehole collared and advanced through quartzite.
Highly fractured 2.1 to 3.0 m - soft-water bearing.
Hole caved back to 2.0 m prior to piezometer installation.

ALL DOWN HOLE DEPTHS, THICKNESSES AND ELEVATION IN METRES.

DRILLING CONTRACTOR	CLIENT
MATHEWS GROUP LTD.	NATIONAL URANIUM TAILINGS PROGRAM

Golder Associates

FORM: G.A.-D-1B

PROJECT No. 841-1334

SUMMARY OF BOREHOLE SO -7d

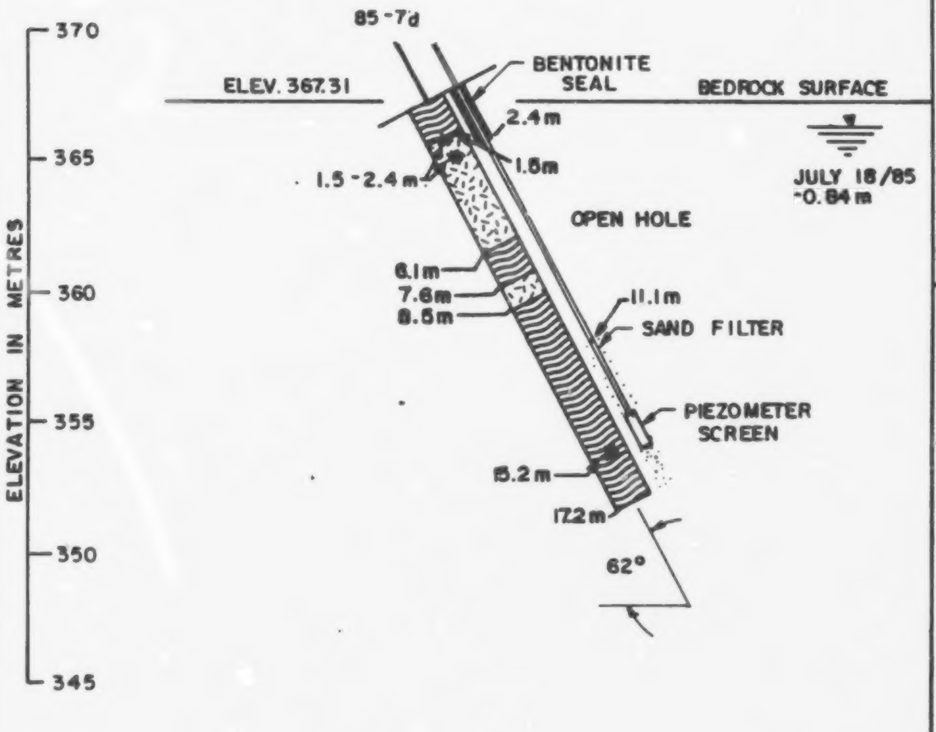
SHEET 1 OF 1

LOCATION OF HOLE	Adjacent to Weir #2 See Figure

DATUM & LEVEL	INCLINATION, AZIMUTH, ALONG HOLE LENGTH	CO-ORDINATES
	62° S.W. 17.16 m. (56ft.4in.)	

TYPE OF DRILLING & MACHINE	CORE BARREL & BIT DESIGN	DRILLING FLUID & FEED	DRILLING DATES
GARDNER DENVER AIR TRACK	BUTTON BIT	AIR FLUSH HYDRAULIC FEED	STARTED June 8/85 COMPLETED June 8/85

SUMMARY LOG



ELEVATION IN METRES
370
365
360
355
350
345
85-7d
ELEV. 367.31
BENTONITE SEAL
BEDROCK SURFACE
2.4 m
1.5 m
1.5 - 2.4 m
JULY 18/85
-0.84 m
OPEN HOLE
6.1 m
7.6 m
8.5 m
11.1 m
SAND FILTER
PIEZOMETER SCREEN
15.2 m
17.2 m
62°

SCALE 1:250 METRIC

DATE LOGGED June 8/85

DATE PHOTOGRAPHED N.A.

LOGGED BY M.W.H.

DRAWN BY D.M.

CHECKED BY M.W.H.

LEGEND

▤ UPPER MISSISSAGI FORMATION QUARTZITE

▨ NIPISSING DIABASE

✱ WATER BEARING ZONE

REMARKS Borehole collared in quartzite which extends to 1.5 m. Diabase 1.5 m to 6.1 m. Quartzite 6.1 m to 7.6 m. Diabase 7.6 to 8.5 m. Quartzite 8.5 m to 17.2 m. Intersected water bearing zone between 1.5 and 2.4 m and 15.2 m. Very hard rock below 15.5 m.

ALL DOWN HOLE DEPTHS, THICKNESSES AND ELEVATION IN METRES.

DRILLING CONTRACTOR	CLIENT
MATHEWS GROUP LTD.	NATIONAL URANIUM TAILINGS PROGRAM

Golder Associates

FORM: G.A.-D-1B

PROJECT No. 84-1334

SUMMARY OF BOREHOLE SO-7e

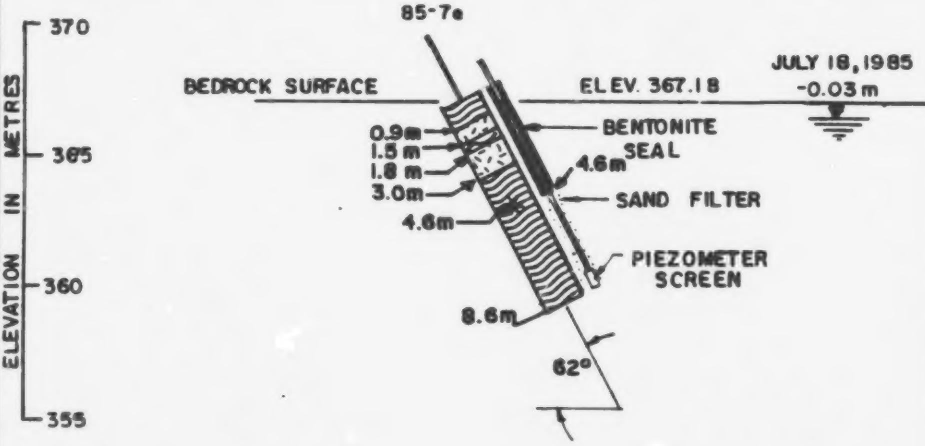
SHEET 1 OF 1

LOCATION OF HOLE Adjacent to Weir #2
See Figure

DATUM & LEVEL	INCLINATION, AZIMUTH, ALONG HOLE LENGTH	CO-ORDINATES
	62° S.W. 8.59 m. (28 ft. 3 in.)	

TYPE OF DRILLING & MACHINE	CORE BARREL & BIT DESIGN	DRILLING FLUID & FEED	DRILLING DATES
GARDNER DENVER AIR TRACK	BUTTON BIT	AIR FLUSH HYDRAULIC FEED	STARTED July 8/85 COMPLETED July 8/85

SUMMARY LOG



85-7e
370
365
360
355
ELEVATION IN METRES
BEDROCK SURFACE
ELEV. 367.18
JULY 18, 1985
-0.03 m
0.9m
1.5 m
1.8 m
3.0m
4.6m
BENTONITE SEAL
4.6m
SAND FILTER
PIEZOMETER SCREEN
8.6m
62°

SCALE 1:250 METRIC

DATE LOGGED July 8/85

DATE PHOTOGRAPHED N.A.

LOGGED BY M.W.H.

DRAWN BY D.M.

CHECKED BY M.W.H.

LEGEND

▤ UPPER MISSISSAGI FORMATION QUARTZITE

▨ NIPISSING DIABASE

* WATER BEARING ZONE

REMARKS Hole collared in quartzite which extends to 0.9 m. Diabase 0.9 to 1.5 m. Quartzite 1.5 to 1.8 m. Diabase 1.8 to 3.0 m. Quartzite 3.0 to 8.6 m. Intersected water bearing zone at 4.6 m. Hole dry above and below that point.

ALL DOWN HOLE DEPTHS, THICKNESSES AND ELEVATION IN METRES.

DRILLING CONTRACTOR MATHEWS GROUP LTD.

CLIENT NATIONAL URANIUM TAILINGS PROGRAM

Golder Associates

FORM: G.A.-D-1B

PROJECT No. 841-1334

SUMMARY OF BOREHOLE SO-7f

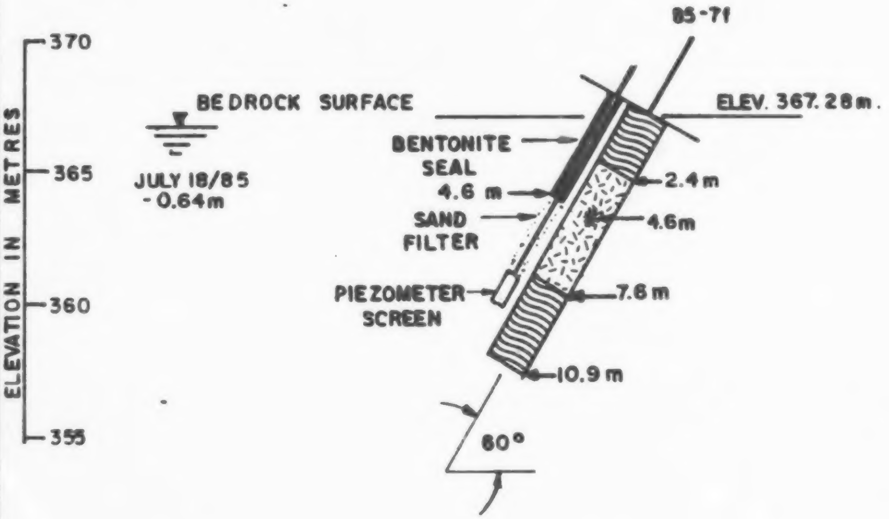
SHEET 1 OF 1

LOCATION OF HOLE Adjacent to Weir #2
See Figure

DATUM & LEVEL	**INCLINATION , AZIMUTH , ALONG HOLE LENGTH** 60° N.E. 10.89 m. (35ft. 9 in.)	**CO-ORDINATES**

TYPE OF DRILLING & MACHINE	**CORE BARREL & BIT DESIGN**	**DRILLING FLUID & FEED**	**DRILLING DATES**
GARDNER DENVER AIR TRACK	BUTTON BIT	AIR FLUSH HYDRAULIC FEED	**STARTED** June 8/85 **COMPLETED** June 8/85

SUMMARY LOG



ELEVATION IN METRES
370
365
360
355
BEDROCK SURFACE
JULY 18/85
-0.64m
85-7f
ELEV. 367.28m.
BENTONITE SEAL
4.6 m
SAND FILTER
PIEZOMETER SCREEN
2.4m
4.6m
7.6m
10.9m
60°

DATE LOGGED June 8/85

DATE PHOTOGRAPHED N.A.

LOGGED BY M.W.H.

DRAWN BY D.M.

CHECKED BY M.W.H.

LEGEND

- ▤ UPPER MISSISSAGI FORMATION QUARTZITE
- ▨ NIPISSING DIABASE
- ✱ WATER BEARING ZONE

SCALE 1:250 METRIC

REMARKS Hole collared on quartzite that gave red cuttings to 2.4 m, soft diabase 2.4 to 7.6 m, soft quartzite 7.6 to 10.9 m. Intersected water bearing zone at 4.6 m

ALL DOWN HOLE DEPTHS, THICKNESSES AND ELEVATION IN METRES.

DRILLING CONTRACTOR MATHEWS GROUP LTD.	**CLIENT** NATIONAL URANIUM TAILINGS PROGRAM

Golder Associates

FORM: G.A - D - I B

APPENDIX I.3

LIST OF TAILINGS SOLIDS SAMPLES

LIST OF SAMPLES

SITE SO-01

BOREHOLE NO.	MATERIAL TYPE	TESTS CARRIED OUT	SAMPLE SOURCE	FIELD SAMPLE NUMBER & TYPE OF CONTAINER				PROJECT SAMPLE NO.
				GLASS JAR 500 mL	THIN WALL TUBE	PLASTIC BAG		
						BEAK	OTHER	
SO-1A	Biege, fine-medium SAND		1'6" (0.46m)			#2		SO-01/A /B2
	Biege, fine-medium SAND		1'-1'9" (0.30-0.53m)	#1				SO-01/A1/J
	Biege, fine-medium SAND with thin silt bands		1'9"-2'3" (0.53-0.69m)	#2				SO-01/A2/J
	Medium grey, fine-medium SAND		2'3"-4' (0.69-1.22m)	#3				SO-01/A3/J
	Medium grey, fine-medium SAND		2'6" (0.76m)			#3		SO-01/A /B3
	Medium grey, fine-medium SAND		6'-8' (1.83-2.44m)	#4				SO-01/A4/J
	Medium grey, fine-medium SAND		9'-14' (2.74-4.27m)				#5 1 kg.bag	SO-01/A5/PB
	Medium grey, fine-medium SAND		16'-18' (4.88-5.49m)				#6 1 kg.bag	SO-01/A6/PB
	Medium grey, fine-medium SAND	B,Ch,M, M&H	20'-22'6" (6.10-6.86m)	#7				SO-01/A7/J
	Medium grey, fine-medium SAND		22'6"-23'6" (6.86-7.16m)	#8		#4		SO-01/A8/J SO-01/A /B4
	Medium dark grey, fine-medium SAND & GRAVEL		23'6"-26' (7.16-7.92m)	#9				SO-01/A9/J
	Medium dark grey, fine-medium SAND & GRAVEL		25' (7.62m)			#5		SO-01/A /B5
	Medium grey, silty sand & gravel TILL	B	26'-27' (7.92-8.23m)	#10				SO-01/A10/J
SO-1B	ROCK CORE Grey Quartzite		28'8"-43'3" (8.74-13.18m)	N/A	N/A	N/A	N/A	SO-01/B /RC
SO-1C	Biege, fine-medium SAND		0-2' (0-0.62m)	2 3/4" #1 Shelby				SO-01/C1/SS
	Medium grey, fine-medium SAND	M&H,WC,K	4'-6' (1.22-2.44m)	2 3/4" #2 Shelby				SO-01/C2/SS
	Medium grey, fine-medium SAND		9'-11' (2.74-3.35m)	2 3/4" #3 Shelby				SO-01/C3/SS
	Medium grey, fine-medium SAND		14'-16' (4.27-4.88m)	2 3/4" #4 Shelby				SO-01/C4/SS
	Medium grey, fine-medium SAND	M&H,WC,K	19'-21' (5.79-6.40m)	2 3/4" #5 Shelby				SO-01/C5/SS
	Medium grey, fine-medium SAND & GRAVEL		24'-25' (7.32-7.62m)	2 3/4" #6 Shelby				SO-01/C6/SS

TEST TYPES

M&H	Sieve & Hydrometer	Geotechnical
WC	Water Content	
K	Hydraulic Conductivity	
B	Barringer	Chemical
BK	Beak	
Ch	Chemex	Radiochemical
M	Monenco	

LEGEND

J - JAR 500 mL
PB - PLASTIC BAG
PS - PLASTIC SHELBY 75 mm ID X 76cm
SS - STEEL SHELBY 70 mm ID x 61cm
B# - IEC BEAK, BACTERIAL SAMPLE
RC - ROCK CORE

LIST OF SAMPLES

SITE SO-02

BOREHOLE NO.	MATERIAL TYPE	TESTS CARRIED OUT	SAMPLE SOURCE	FIELD SAMPLE NUMBER & TYPE OF CONTAINER				PROJECT SAMPLE NO.
				GLASS JAR 500 mL	THIN WALL TUBE	PLASTIC BAG		
						BEAK	OTHER	
SO-2A	Very light grey, fine-medium SAND		0.5'-1.5' (0.15-0.46m)	#1				SO-02/A1/J
	Light-medium grey, fine-medium SAND, occas. silt		0.7' (0.21m)			#1		SO-02/A /B1
	Light-medium grey, fine-medium SAND, occas. silt		1.5' (0.46m)			#2		SO-02/A /B2
	Light-medium grey, fine-medium SAND, occas. silt		3.3' (1.0m)			#3		SO-02/A /B3
	Light-medium grey, fine-medium SAND, occas. silt		2.5'-4' (0.76-1.22m)	#2				SO-02/A2/J
	Light-medium grey, fine-coarse SAND, occas. silt	B,Ch,M&H WC	10.5'-13' (3.20-3.96m)		#3			SO-02/A3/PS
	Light-medium grey, fine-coarse SAND, occas. silt		13'-14' (3.96-4.27m)	#4				SO-02/A4/J
	Light-medium grey, fine-coarse SAND		22'-24' (6.71-7.32m)	#5				SO-02/A5/J
	Light-medium grey, fine-coarse SAND	B,Ch,M&H WC	25.5'-28' (7.77-8.53m)		#6			SO-02/A6/PS
	Light-medium grey, fine-coarse SAND		28.5' (8.69m)			#4		SO-02/A /B4
	Medium grey, fine-medium SAND, trace of silt		32'-34' (9.75-10.36m)	#7				SO-02/A7/J
	Medium grey, fine-medium SAND, trace of silt	B,Ch,M&H	35.5'-38' (10.82-11.58m)		#8			SO-02/A8/PS
	Medium grey, fine-medium SAND		42'-44' (12.80-13.41m)	#9				SO-02/A9/J
SO-2D	Light-medium grey, fine-medium SAND	B,Ch,M&H WC	1'-3' (0.30-0.91m)		2 3/4" Shelby #1			SO-02/D1/SS
	Light-medium grey, fine-medium SAND, occas. silt	B,Ch,M&H WC	5'-7' (1.52-2.13m)		2 3/4" Shelby #2			SO-02/D2/SS

TEST TYPES

M&H Sieve & Hydrometer
WC Water Content
K Hydraulic Conductivity } Geotechnical

B Barringer
BK Beak } Chemical

Ch Chemex
M Monenco } Radiochemical

LEGEND

J - JAR 500 mL
PB - PLASTIC BAG
PS - PLASTIC SHELBY 75 mm ID x 76cm
SS - STEEL SHELBY 70 mm ID x 61cm
B# - IEC BEAK, BACTERIAL SAMPLE
RC - ROCK CORE

LIST OF SAMPLES

SITE SO-03

BOREHOLE NO.	MATERIAL TYPE	TESTS CARRIED OUT	SAMPLE SOURCE	FIELD SAMPLE NUMBER & TYPE OF CONTAINER				PROJECT SAMPLE NO.
				GLASS JAR 500 mL	THIN WALL TUBE	PLASTIC BAG		
						BEAK	OTHER	
SO-3A	Light brown, fine-medium SAND		1'-2' (0.3-0.6m)	#1				SO-03/A1/J
	Light brown, fine-medium SAND		0'-1' (0.0-0.3m)			#1		SO-93/A0/B1
	Light brown, fine-medium SAND		1'-2' (0.3-0.6m)			#2		SO-03/A /B2
	Dark reddish brown, fine-medium SAND		2'-3' (0.6-0.9m)			#3		SO-03/A /B3
	Medium reddish brown, fine-medium SAND		3'-4.5' (0.9-1.4m)	#2				SO-03/A2/J
	Dark grey, fine-medium SAND, silt bands		7'-8' (2.1-2.4m)	#3a				SO-03/A3a/J
	Dark grey, very fine SILTS-SLIMES, occ. SANDS		9'-10' (2.7-3.0m)	#3b				SO-03/A3b/J
	Dark grey, very fine SILTS-SLIMES, occ. SANDS		10.5'-13' (3.2-4.0m)	#4				SO-03/A4/J
	Dark grey, very fine SILTS-SLIMES		13'-15' (4.0-4.6m)	#5a				SO-03/A5a/J
	Black, very fine SILTS		16'-18' (4.9-5.5m)	#5b				SO-03/A5b/J
	Black, very fine SILTS		18'-20' (5.5-6.1m)			#4		SO-03/A /B3
	Dark grey, fine-medium SILTS & SANDS		20'-21.5' (6.1-6.6m)	#6				SO-03/A6/J
	Very dark grey, very fine SILTS-SLIMES, occ. SANDS		24'-26' (7.3-7.9m)	#7a				SO-03/A7a/J
	Light-dark grey, fine SILTS & SANDS-layered		27'-28' (8.2-8.5m)	#7b				SO-03/A7b/J
	Light grey, fine-very fine SILTS-SLIMES		28'-31.5' (8.5-9.6m)	#8a				SO-03/A8a/J
	Dark grey-black, fine-medium SILTS, occ. SANDS		31.5'-33' (9.6-10.1m)	#8b				SO-03/A8b/J
	Very dark grey, fine SILTS		35'-36' (10.7-11.0m)	#9				SO-03/A9/J
	Dark brownish grey, SILTY SAND & GRAVEL TILL		38'-39.5' (11.6-12.0m)	#10				SO-03/A10/J
								SO-03/A /B5
	Dark brownish grey, SILTY SAND & GRAVEL TILL		41'-41.5' (12.5-12.6m)	#11		#5		SO-03/A11/J
SO-3B	Dark grey, fine-medium SAND, SILT bands		4.3'-6.8' (1.3-2.1m)		#1			SO-03/B1/PS
	Dark grey, very fine SILTS-SLIMES	M&H,WC,K	13'-15.5' (4.0-4.7m)		#2			SO-03/B2/PS
	Black, very fine SILTS		15.5'-18.0' (4.7-5.5m)		#3			SO-03/B3/PS
	Dark grey, fine-medium SILTS & SANDS		21'-23.5' (6.4-7.2m)		#4			SO-03/B4/PS
	Very dark grey, very fine SILTS - SLIMES	K	23.5'-26' (7.2-7.9m)		#5			SO-03/B5/PS
	Light grey, fine-very fine SILTS - SLIMES		29'-31' (8.8-9.4m)		[illegible]-3/4" #6 Shelby			SO-03/B[illegible]/SS

TEST TYPES

M&H	Sieve & Hydraulic	
WC	Water Content	Geotechnical
K	Hydraulic Conductivity	
B	Barringer	Chemical
BK	Beak	
Ch	Chemex	Radiochemical
M	Monenco	

LEGEND

J - JAR mL
PB - PLASTIC BAG
PS - PLASTIC SHELBY 75 mm ID x 76cm
SS - STEEL SHELBY 70 mm ID x 61cm
B# - IEC BEAK, BACTERIAL SAMPLE
RC - ROCK CORE

LIST OF SAMPLES

SITE SO-04

BOREHOLE NO.	MATERIAL TYPE	TESTS CARRIED OUT	SAMPLE SOURCE	FIELD SAMPLE NUMBER & TYPE OF CONTAINER				PROJECT SAMPLE NO.
				GLASS JAR 500 mL	THIN WALL TUBE	PLASTIC BAG		
						BEAK	OTHER	
SO-4A	Very light grey, fine-medium SAND		0.5'-1' (0.15-0.30m)	#1		#2		SO-04/A1/J SO-04/A /B2
	Medium grey, fine-medium SAND, occ. SILT SLIME BANDS		2' (0.61m)			#3		SO-04/A /B3
	Medium grey, fine-medium SAND, occ. SILT-SLIME		3.5'-5.5' (1.07-1.68m)	#2				SO-04/A2/J
	Interlayered, medium grey SAND & medium-dark SILT-SLIME		10.5'-11' (3.20-3.35m)	#3				SO-04/A3/J
	Interlayered, dar-medium grey, SILT-SLIMES & occasional medium-grey, fine-medium SAND		19.5'-20.5' (5.94-6.25m) 20' (6.10m)	#4		#4a		SO-04/A4/J SO-04/A /B4a
	Medium grey, fine SANDY SILT		20.5'-22.5' (6.25-6.86m)		2 3/4" Shelby #5			SO-04/A5/SS
	Very dark grey, very fine SILT SLIMES		23'-23.5' (7.01-7.16m)	#6				SO-04/A6/J
	Very dark grey, very fine SILT SLIMES	M&H,WC	24'-26' (7.32-7.92m)		2 3/4" Shelby #7			SO-04/A7/SS
	Dark-medium grey, very fine SILT-SLIMES, occ. SAND		28'-29' (8.53-8.84m)	#8				SO-04/A8/J
	Medium grey, fine SILTY SAND		29'-31' (8.84-9.45m)		2 3/4" Shelby #9			SO-04/A9/SS
	Medium-dark grey, very fine SILT-SLIMES		31'-32.5' (9.45-9.91m)	#10				SO-04/A10/J
	Medium-dark grey, very fine SILT-SLIMES		32.0' (9.75m)			#4b		SO-04/A/B4b
	Brown, SILTY SAND & GRAVEL TOPSOIL	B	32.5'-33' (9.91-10.06m)	#11		#5a		SO-04/A11/J SO-04/A/B5a
	Medium-reddish brown, SILTY SAND & GRAVEL TIL	B	34'-36' (10.36-10.97m)	#12				SO-04/A12/J
	Medium-reddish brown, SILTY SAND & GRAVEL TILL		35' (10.67m)			#5b		SO-04/A /5b
SO-4B	Light-medium grey, fine-medium SAND	1 B,Ch,M 2 B,Ch	3'-5' (0.91-1.52m)		2 3/4" Shelby #1			SO-04/B1/SS
	Medium-grey, SILTY SAND	B,Ch,M	9'-11' (4.18-3.35m)		2 3/4" Shelby #2			SO-04/B2/SS
	Medium-grey, SILT SLIMES	B,Ch	14'-16' (4.27-4.88m)		2 3/4" Shelby #3			SO-04/B3/SS
SO-4C			4"-6" (0.10-0.15m)			#1		SO-04/C /B1

TEST TYPES

M&H	Sieve & Hydraulic	Geotechnical
WC	Water Content	
K	Hydraulic Conductivity	
B	Barringer	Chemical
BK	Beak	
Ch	Chemex	Radiochemical
M	Monenco	

LEGEND

J - JAR 500 mL
PB - PLASTIC BAG
PS - PLASTIC SHELBY 75 mm ID X 76cm
SS - STEEL SHELBY 70 mm ID x clcm
B* - IEC BEAK, BACTERIAL SAMPLE
RC - ROCK CORE

LIST OF SAMPLES

SITE SO-05

BOREHOLE NO.	MATERIAL TYPE	TESTS CARRIED OUT	SAMPLE SOURCE	FIELD SAMPLE NUMBER & TYPE OF CONTAINER				PROJECT SAMPLE NO.
				GLASS JAR 500 mL	THIN WALL TUBE	PLASTIC BAG		
						BEAK	OTHER	
SO-5A	Medium dry, very fine SILT-SILT SLIMES 1;2;3	B;B;Ch;M&H	3'-5.5' (0.91-1.68m)		#1			SO-05/A1/PS
SO-5B	Medium brown, SILTY SAND & GRAVEL		1'-2' (0.30-0.61m)				100g #1	SO-05/B /PB1
	Light grey, laminated, fine-medium SAND		2'-3.5' (0.61-1.07m)	#1		#2	3 kg #2	SO-05/B1/J SO-05/B /B2 SO-05/B /PB2
	Medium grey, very fine SILT-SILT SLIMES		4'-5' (1.22-1.58m)			#3	100g #3	SO-05/B /B2 SO-05/B /PB3
	Medium grey, very fine SILT-SILT SLIMES		6'-7.5' (1.83-2.29m)	#2				SO-05/B2/J
	Medium grey, very fine SILT-SILT SLIMES		3.5'-7.5' (1.07-2.29m)				3 kg #4	SO-05/B /PB4
	Medium grey, very fine SILT-SILT SLIMES		8'-9' (2.44-2.74m)	#3			100g #5	SO-05/B3/J SO-05/B /PB5
	Medium grey, very fine SILT-SILT SLIMES		10'-12.5' (3.05-3.81m)	#4				SO-05/B4/J
	Medium grey, very fine SILT-SILT SLIMES		11'-12' (3.35-3.66m)				100g #6	SO-05/B /PB6
	Medium grey, very fine SILT-SILT SLIMES		15' (4.57m)				100g #7	SO-05/B /PB7
	Medium grey, very fine SILT-SILT SLIMES		16'-17.5' (4.88-5.33m)	#5				SO-05/B5/J
	Medium grey, very fine SILT-SILT SLIMES		18' (5.49m)				100g #8	SO-05/B /PB8
	Medium grey, very fine SILT-SILT SLIMES		21' (6.40m)				100g #9	SO-05/B /PB9
	Light-dark grey, fine-medium SILTY SAND		23'-26' (7.01-7.92m)	#6				SO-05/B6/J
	Light-dark grey, fine-medium SILTY SAND		24' (7.32m)				100g #10	SO-05/B /PB10
	Light-dark grey, fine-medium SILTY SAND		26'-27' (7.92-8.23m)	#7				SO-05/B7/J
	Light-dark grey, fine-medium SILTY SAND		27' (8.23m)				100g #11	SO-05/B /PB11
	Light-dark grey, fine-medium SILTY SAND		30' (9.14m)				100g #12	SO-05/B /PB12
	Light-dark grey, fine-medium SILTY SAND		33' (10.06m)				100g #13	SO-05/B /PB13
	Light-dark grey, fine-medium SILTY SAND		37.5'-40' (11.43-12.19m)	#8				SO-05/B8/J
	Light-dark grey, fine-medium SILTY SAND		39' (11.89m)				100g #14	SO-05/B /PB14
	Light-dark grey, fine-medium SILTY SAND		41' (12.50m)				100g #15	SO-05/B /PB15
	Light-dark grey, fine-medium SILTY SAND		45' (13.72m)				100g #16	SO-05/B /PB16
	Light-dark grey, fine-medium SILTY SAND		45.5' (13.87m)			#4		SO-05/B /B4
	Dark brown, fibrous PEAT		46.5'-47.5' (14.17-14.48m)	#9			100g #17	SO-05/B9/J SO-05/B /PB17
	Dark brown, fibrous PEAT		48' (14.63m)			#5a		SO-05/B /5a
	Dark brown, fibrous PEAT		51' (15.54m)				100g #18	SO-05/B /PB18
	Light-medium grey, fine-medium SAND		52'-52.5' (15.85-16.00m)	#10				SO-05/B10/J
	Medium-grey, medium-coarse SAND & GRAVEL	B	52.5'-55.5' (16.00-16.92m)	#11				SO-05/B11/J
	Medium-grey, medium-coarse SAND & GRAVEL		54' (16.46m)			#5b		SO-05/B /B5b
	Medium-grey, medium-coarse SAND & GRAVEL		55' (16.76m)				100g #19	SO-05/B /PB19
	Light-grey, fine SILTY SAND	B	64.5'-66.5' (19.66-20.27m)	#12				SO-05/B12/J
	Light-grey, fine SILTY SAND		65'-67' (19.81-20.42m)				100g #20	SO-05/B /PB20
	Light-grey, fine SILTY SAND	M&H,WC	69'4"-71'4" (21.13-21.74m)	#13				SO-05/B13/J
	Light grey, fine SILTY SAND		71'4"-73'4" (21.74-22.35m)				100g #21	SO-05/B /PB21
SO-5G	Medium grey, very fine SILT-SILT SLIMES	B,Ch,M&H,WC	14'-17.5' (4.27-5.33m)		#1			SO-05/G1/PS
	Medium grey, very fine SILT-SILT SLIMES		18.5'-21' (5.64-6.40m)		#2			SO-05/G2/PS
	Medium grey, very fine SILT-SILT SLIMES	B,Ch,M&H,WC	21'-23.5' (6.40-7.16m)		#3			SO-05/G3/PS
	Light-dark grey, fine-medium SILTY SAND	B,Ch,M&H,WC	36'-38.5' (10.97-11.73m)		#4			SO-05/G4/PS
	Dark brown, fibrous peat	B,Ch	50-52.5' (15.24-16.00m)		#5			SO-05/G5/PS
	Light-dark grey, fine-medium SILTY SAND	B,M&H,WC	52.5'-55' (16.00-16.76m)		#6			SO-05/G6/PS

TEST TYPES

M&H	Sieve & Hydraulic	Geotechnical
WC	Water Content	
K	Hydraulic Conductivity	
B	Barringer	Chemical
BK	Beak	
Ch	Chemex	Radiochemical
M	Monenco	

LEGEND

J - JAR 500 mL
PB - PLASTIC BAG
PS - PLASTIC SHELBY 75 mm ID x 76cm
SS - STEEL SHELBY 70 mm ID x 61cm
B# - IEC BEAK, BACTERIAL SAMPLE
RC - ROCK CORE

Number/
Numéro

2

CONTRACT SERIAL NUMBER: OSQ84-00196

CONTRACTOR: Golder Associates

REQUISITION NUMBER: 23241-4-1680

LACNOR FIELD STUDY
ELLIOT LAKE, ONTARIO

APPENDIX 2

METEOROLOGY, AIR QUALITY AND RADIOACTIVITY

Prepared for

The National Uranium Tailings Program

By

Golder Associates

Beak Consultants SENES Consultants

Cumming - Cockburn & Associates

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APPENDIX 2 METEOROLOGY, AIR QUALITY AND RADIOACTIVITY

2.1 Introduction

2.1.1 Scope and Objectives

In December, 1984, Golder Associates, SENES Consultants, Beak Consultants and Cumming-Cockburn were awarded a contract by the National Uranium Tailings Program (NUTP) to carry out the field study at the Lacnor uranium tailings area in Elliot Lake, Ontario. The intent of the project, as set out in the terms of reference was:

> "The design and operation of a sampling program, incorporating chemical, physical and biological data that will be used to characterize the Lacnor tailings and environs, and which will provide raw data for the study of processes involving tailings constituents and their pathways."

The field study therefore required the sampling of tailings solids, sub-tailings soil and rock, the surrounding soil and rock, tailings porewater, surface water, the measurement of surface water runoff, the gathering of atmospheric data and a biological assessment of the site.

This appendix (Appendix 2 to the main overview report) includes details regarding the meteorology, air quality and selected radiological parameters on, and in the immediate vicinity of, the Lacnor uranium tailings area. Details of the field work carried out during the period of December 1984 to October 1985 and all the results obtained are presented in this factual report. Overall interpretation of these results has been excluded from this study.

2.1.2 Appendix Outline

This appendix is organized into the following sections:

2.2 Meteorology, presents the results of meteorological monitoring at three locations - one on the Lacnor tailings area and two off-site locations. The parameters measured include wind speed, wind direction, temperature, precipitation, solar radiation, evaporation, relative humidity, barometric pressure and snow course measurements.

2.3 Air Quality, presents the results of air quality monitoring at ten sites located on and in the immediate vicinity of the tailings area. Concentration suspended particulate matter was measured at two sites, while dustfall levels were measured at eight sites.

2.4 Radioactivity presents the results of radon monitoring at twelve sites in the immediate vicinity of the tailings area; radon exhalation measurements from the surface of the tailings at over twenty sites; and gamma radiation levels over the surface of the tailings.

2.1.3 Schedule of Events

Two of the meteorological stations were carry-overs from a previous NUTP study and therefore were in operation from the onset of the contract. The third station was installed near the center of the tailings area in mid-December 1984. The air quality monitoring equipment was installed in mid January along with the radon monitoring devices.

Radon flux (emanation) measurements were made during March, June and July 1985. Surface gamma measurements were made during June and July 1985. The field measurements for the air quality, radioactivity, and meteorological programs were terminated at the end of October 1985.

2.2 Meteorology

2.2.1 Station Locations and Equipment

During the Lacnor field study, meteorological conditions were monitored at three locations using various meteorological equipment.

The Lacnor station (MT-01) located on the tailings area, was the main meteorological station and is shown on Figure 2.1. At this site wind speed and direction were measured on a continuous basis at a height of 10 metres; solar radiation was measured using a sensitive weather proof pyranometer; and temperature was measured on a continuous basis using a precision thermilinear probe. Both the temperature and solar radiation sensors were mounted on the tower at a height of approximately 2.5 m. These measurements were made using a Climatronics Electronic Weather Station (EWS). A Class A evaporation pan and Sacramento totalizing precipitation gauge were also in operation at the Lacnor station. The evaporation pan was operated from May to October and was attended every three or four days. Measurements of the total precipitation level in the Sacramento gauge were made approximately once or twice a week from late December to the end of October.

The Nordic Tower site (MT-02), a carry-over from a previous NUTP radon monitoring program in the Elliot Lake area, was located to the south of Lacnor MT-01 on the Nordic tailings area. At this station, wind speed and direction were measured at a height of 10 m using a MRI Mechanical Weather Station for the period of December 1984 to June 1985 and a Climatronics WM-III wind recording system for the period of July to October 1985.

The CAIRS station (MT-03), also a carry-over from the NUTP radon monitoring program, was located on the roof of the CAIRS office at 7 Timmins Road, in the Town of Elliot Lake. At this station, temperature, relative humidity, and barometric pressure were recorded on a continuous basis using a Weathermeasure Meteorograph. Precipitation was also measured at the station using a standard rainfall gauge. During the winter, snowfall was collected in the gauge and melted to yield a rainfall equivalent.

Table 2.2.1 summarizes the meteorological parameters monitored at each site and the periods of operation. Photographs of MT-01 are included at the end of this appendix.

Table 2.2.1: METEOROLOGY - SITE AND PARAMETER SUMMARY

Site	Period of Operation	Meteorological Parameter*	
MT-01 Lacnor station	20 Dec 1984 to 31 Oct 1985	Wind speed Wind direction Temperature Solar radiation Total precipitation Evaporation (Class A)	atop 10 m tower
MT-02 Nordic Tower	14 Jun 1984 to 31 Oct 1985	Wind speed Wind direction	atop 10 m tower
MT-03 CAIRS station	16 Jun 1984 to 28 Oct 1985	Temperature Relative humidity Barometric pressure Precipitation	

Note:

* All parameters measured on a continuous basis except for total precipitation and evaporation at Lacnor station and precipitation at CAIRS station.

2.2.2 Wind

Tables 2.2.2 and 2.2.3 summarize the wind speed and direction data collected at Lacnor station (MT-01) and Nordic Tower (MT-02), respectively. The average monthly wind speed at Lacnor station was 8.7 km/h and ranged from 7.0 km/h in August to 11.0 km/h in March. At MT-02 the average monthly speed was 10.9 km/h and ranged from 7.6 km/h in December to 16.0 km/hr in March. A higher percentage of complete data was gathered for the Lacnor station compared to the Nordic Tower. This is attributable to the greater frequency of visits to the Lacnor station by the field technician.

2.2.3 Temperature

Tables 2.2.4 and 2.2.5 present a summary of the temperature data as measured at the Lacnor and CAIRS stations (MT-03), respectively. The Lacnor station daily mean temperature ranged from -12°C in January to 20°C in July, while for the CAIRS station the daily mean ranged from -12°C in January to 17°C in July. The extreme maximum and extreme minimum temperature recorded at the Lacnor and CAIRS stations were 29°C, -27°C and 28°C, -20°C, respectively.

2.2.4 Precipitation

Tables 2.2.6 and 2.2.7 present a summary of the precipitation data collected at the Lacnor and CAIRS stations. Measurements at the Lacnor station were made using a Sacramento totalizing precipitation gauge, while measurements at the CAIRS station were made using a standard rainfall gauge. The monthly total amounts of precipitation ranged from 38 mm in September to 137 mm in August at the Lacnor station and from 33 mm in January to 103 mm in August at the CAIRS station.

2.2.5 Solar Radiation

Monthly solar radiation levels for the Lacnor station are summarized on Table

Table 2.2.2: **METEOROLOGY - MONTHLY WIND SUMMARY, LACNOR STATION MT-01 (1985)**

	Dec*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Avg. Speed (km/h)	9.2	9.7	8.9	11.0	8.4	9.0	8.8	7.2	7.0	7.9	8.1
Hours of Calm	19	35	29	38	49	21	50	66	69	49	80
Hours of Measured Speed	273	744	672	744	694	744	720	744	741	585	744
% Complete	37	100	100	100	96	100	100	100	99	81	100
Hours of Measured Direction	273	744	663	744	719	744	720	744	741	584	744
% Complete	37	100	99	100	99	100	100	100	99	81	100
Direction (%)											
N	1.1	4.6	4.8	5.4	5.1	4.6	4.0	8.2	6.2	5.1	11.4
NNE	8.4	23.3	15.6	14.0	11.3	11.2	8.1	7.1	5.0	4.6	5.8
NE	7.3	9.7	13.2	11.2	5.1	15.3	6.9	3.0	6.5	3.8	3.8
ENE	13.6	5.0	5.1	7.9	6.7	4.3	2.8	0.5	6.7	7.0	3.0
E	8.1	1.2	2.5	8.5	5.6	3.5	1.9	0.4	5.3	6.8	4.2
ESE	8.1	0.7	0.9	1.7	5.8	3.6	0.7	0.4	1.8	7.4	4.2
SE	2.9	3.5	0.1	0.7	8.3	6.5	2.2	1.3	4.9	3.1	2.0
SSE	2.2	2.6	3.9	1.1	6.5	4.2	3.5	1.6	4.0	1.5	1.1
S	2.9	3.2	7.0	7.1	3.6	5.9	9.0	6.0	6.2	3.4	2.2
SSW	0.4	1.7	5.7	9.3	4.0	4.6	7.2	10.2	6.9	5.8	6.3
SW	0.4	2.3	5.1	6.6	4.5	6.5	6.4	7.9	4.6	4.4	7.3
WSW	5.1	5.9	6.1	7.8	5.3	9.5	5.1	9.0	8.6	9.1	8.9
W	22.0	12.9	11.5	5.0	7.0	7.0	7.6	13.0	10.5	10.1	4.7
WNW	7.3	7.7	2.8	3.9	5.8	3.4	12.5	8.5	5.9	5.0	5.8
NW	3.3	6.9	6.0	4.0	5.1	4.6	11.8	9.3	5.5	7.4	8.1
NNW	0.0	4.3	4.2	0.8	3.3	2.7	3.2	4.6	2.0	7.0	10.8

Note:

* Instrumentation set up 20 December 1984.

Table 2.2.3: METEOROLOGY - MONTHLY WIND SUMMARY, NORDIC TOWER MT-02 (1985)

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Avg. Speed (km/h)	7.6	12.4	11.3	16.0	12.3	12.0	13.2	9.4	8.3	8.6	8.3
Hours of Calm	14	34	59	0	22	0	0	1	16	13	18
Hours of Measured Speed	415	583	606	371	649	610	298	372	744	506	428
% Complete	58	78	90	50	90	82	41	50	100	70	58
Hours of Measured Direction	333	564	587	353	621	602	292	350	744	506	429
% Complete	46	76	87	47	86	81	41	47	100	70	58
Direction (%)											
N	7.4	7.9	2.1	2.1	4.0	5.6	4.0	13.4	8.7	8.5	4.4
NNE	2.1	10.3	2.3	8.0	4.9	4.4	6.4	4.0	5.5	6.1	4.0
NE	1.0	8.6	12.2	11.4	4.3	10.3	3.4	1.9	6.6	4.9	3.7
ENE	4.0	4.3	7.1	14.4	5.2	9.2	2.0	1.1	8.1	3.8	7.7
E	3.8	4.5	2.1	8.3	2.8	2.6	2.0	0.5	8.1	5.5	11.2
ESE	14.5	5.3	5.6	8.0	13.9	8.4	1.7	1.9	5.0	7.5	10.0
SE	3.3	6.5	3.1	4.8	11.1	11.6	3.7	4.6	4.7	9.7	6.0
SSE	5.7	2.9	5.6	7.8	4.3	6.6	4.4	5.9	3.6	6.5	5.3
S	1.7	0	1.1	0	0.6	1.6	2.3	5.1	4.4	5.7	2.8
SSW	2.1	0.9	3.4	4.5	2.5	6.2	4.4	7.3	4.2	6.3	3.0
SW	0.2	0.9	6.1	4.5	6.9	6.1	7.4	7.5	8.5	8.3	3.5
WSW	3.8	3.9	4.5	5.1	4.9	9.2	7.7	5.6	6.3	5.3	5.3
W	6.4	6.3	7.2	1.6	3.1	2.6	8.1	11.0	9.7	4.0	10.9
WNW	14.0	9.4	8.4	2.7	7.9	8.0	16.1	9.4	5.1	5.1	5.6
NW	3.8	9.9	7.4	8.3	7.6	2.8	14.4	8.3	4.2	2.4	6.7
NNW	1.9	9.4	6.8	2.7	8.3	3.4	10.1	6.2	5.2	7.5	5.3

Table 2.2.4: METEOROLOGY - MONTHLY TEMPERATURE SUMMARY, LACNOR STATION MT-01 (1985)

	Dec*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep**	Oct
Daily Mean	-10	-12	-9	-4	4	11	15	20	19	13	6
Mean Max.	-5.3	-7.7	-4.9	0.9	8.7	15.7	19.3	24.6	23.1	16.3	9.6
Mean Min.	-14.1	-15.7	-13.8	-8.0	-0.5	6.9	10.1	15.6	15	9.4	2.0
Monthly Max.	3	-2	4	7	24	23	29†	29†	29†	26	14
Monthly Min.	-22	-26	-27	-21	-11	0	4	10	11	3	-4

Notes:

* Instrumentation set up 20 December 1984.
** Several days without data.
† Upper limit of sensitivity.
All temperatures measured in °C.

Table 2.2.5: METEOROLOGY - MONTHLY TEMPERATURE SUMMARY, CAIRS STATION MT-03 (1985)

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Daily Mean	-6	-12	-10	-3	4	12	13	17	16.5	12	7
Mean Max.	-3	-8.5	-6	-0.5	7	16	18	22	21	17	11
Mean Min.	-10	-15	-13	-5	1	7.5	9	12.5	12	8	3
Monthly Max.	7	-3	4	3	24	24	28	26	25	25	15
Monthly Min.	-20*	-20*	-20*	-13	-5	0	4	7	8	2	-3

Notes:

* Lower limit of detection.

All measurements in °C.

Table 2.2.6: METEOROLOGY - MONTHLY PRECIPITATION SUMMARY, LACNOR STATION MT-01 (1985)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
From	19 Dec	1 Feb	28 Feb	1 Apr	5 May	31 May	3 Jul	29 Jul	3 Sep	1 Oct
To	1 Feb	28 Feb	1 Apr	5 May	31 May	3 Jul	29 Jul	3 Sep	1 Oct	28 Oct
No. of days	44	27	32	34	26	33	26	36	28	27
Total (mm)	57	44	61	87	60	52	93	137	38	66

Note:

All measurements made using a Sacramento Totalizing Precipitation Gauge.

Table 2.2.7: METEOROLOGY - MONTHLY PRECIPITATION SUMMARY, CAIRS STATION MT-03 (1985)

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Total (mm)	80.5	32.8	50.8	69.1	47.0	54.4	47.0	92.5	102.9	61.5	74.7

Table 2.2.8: METEOROLOGY - MONTHLY SOLAR RADIATION SUMMARY, LACNOR STATION MT-01 (1985)

	Dec*	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Days of Record	11	31	28	31	29	31	30	31	30	22	31
Monthly Total*	596	2944	4538	8882	10904	13360	15338	14540	11416	5496	5406
Daily Mean*	54	95	162	286	376	431	518	469	381	250	174
Daily Max.*	98	164	334	474	590	668	700	646	636	444	324
Daily Min.*	10	26	26	42	36	56	96	58	54	42	10

Notes:

* Instrumentation set up 20 December 1984.

All measurements in Langleys (1 Langley = 1 cal/cm^2).

2.2.8. The monthly totals range from a low of 2944 Langleys in January to a high of 15338 Langleys in June. The mean daily solar radiation ranged from 95 Langleys in January to 518 Langleys in June. (One Langley is equivalent to one calorie per square centimetre.)

2.2.6 Evaporation (Class A Pan)

The monthly evaporation as measured at the Lacnor station, is summarized on Table 2.2.9. The class A evaporation pan assembly was in operation during the period of 1 May to 31 October 1985. Monthly evaporation ranged from 34 mm in October to 178 mm in July.

2.2.7 Relative Humidity

Table 2.2.10 presents a summary of the levels of relative humidity measured at the CAIRS station. The daily means ranged from a low of 51% in May and June to a high of 68% in December. Measurements were made using a Meteorograph equipped with a human hair bundle to sense changes in levels of relative humidity.

2.2.8 Barometric Pressure

Table 2.2.11 presents a summary of the barometric pressure levels measured at the CAIRS station. Pressure measurements were recorded using a Meteorograph equipped with a 14-cell 51 mm diameter aneroid pressure sensor.

2.2.9 Snow Depth and Water Equivalent

The depth of snow and water equivalent were measured during two separate winter-period campaigns, with the samplng sites located on the tailings. The first campaign was conducted in early March as part of the radon flux (RF) measurement program. At each of the RF locations, shown on Figure 2.1, cores of snow were taken and melted to determine the water equivalent. A second program was conducted in early April just prior to the spring freshet. The

Table 2.2.9: **METEOROLOGY - MONTHLY EVAPORATION SUMMARY, LACNOR STATION MT-01 (1985)**

	May	Jun	Jul	Aug	Sep	Oct
Total Evaporation (mm)	136	120	178	111	55	34
Total Wind run (km)	4897	4156	4041	3163	3633	4080
Mean Water Temp. (°C)	13	15.5	19	19	14	8
Mean Max. Water Temp. (°C)	21	24	27	26	21	13
Mean Min. Water Temp. (°C)	5.5	7	10.5	12	7	3
Monthly Max. Water Temp. (°C)	25.5	29	31	31	30	19
Monthly Min. Water Temp.(°C)	1.5	3	6.5	10	3.5	0.5

Table 2.2.10: METEOROLOGY - MONTHLY RELATIVE HUMIDITY SUMMARY, CAIRS STATION MT-03 (1985)

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Daily Mean	68	65	62	52	58	51	51	52	57	61	58
Mean Max.	79	76	73	72	74	69	71	73	75	77	76
Mean Min.	57	54	51	31	42	33	31	30	39	44	41
Monthly Max.	86	84	82	84	83	83	82	76	80	80	81
Monthly Min.	42	34	26	10	15	4(1)	12	16	16	25	12

Note:

All measurements in per cent relative humidity.
(1) Questionable value.

Table 2.2.11: METEOROLOGY - MONTHLY BAROMETRIC PRESSURE SUMMARY, CAIRS STATION MT-03 (1985)

	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Daily Mean	100.2	99.9	100.1	100.2	99.9	99.8	99.7	99.8	100.2	100.3	100.2
Daily Max.	101.6	101.6	101.2	101.9	101.7	100.9	100.6	100.6	101.0	102.0	101.8
Daily Min.	98.7	98.6	99.0	99.0	97.7	98.3	98.3	99.0	99.2	99.4	98.3

Note:

All measurements in kilopascals.

depth of the snow pack had reduced some 31 cm in depth between the two sample programs, however the water equivalent volume did not changed appreciably.

Table 2.2.12 summarizes the data obtained during the two programs. Also noted on the table is the depth of ice covering the tailings at each of the sampling locations.

For the mid winter program in March, eighteen samples were collected on the tailings area. The average snow depth was 54.8 cm and ranged from 35.6 cm to 68.6 cm. The snow cores collected ranged in volume from 1623 mL to 3128 mL and, after melting, resulted in water equivalent volumes ranging from 435 mL to 1030 mL. The average ratio of snow volume to water volume was 3.6 and ranged from 3.0 to 5.3

For the pre-freshet program eighteen samples were collected on the tailings area at the same locations as in the March program. The average snow depth was 24.0 cm and ranged from 11.2 cm to 32.0 cm. The snow cores collected ranged in volume from 511 mL to 1459 mL. Five samples were melted and these resulted in water equivalent volumes ranging from 430 mL to 1020 mL. The average water equivalent volume was very similar to the March program result of 688 mL, however, the average ratio of snow volume to water volume had reduced to 1.9.

2.3 Air Quality

2.3.1 Monitoring Locations

Air quality was monitored at eight locations for dustfall and at two locations for suspended particulate matter (SPM). Figure 2.1 depicts the locations of the sampling sites. Dustfall was measured at stations AQ-01 to AQ-08, while SPM was measured at AQ-09 and AQ-10. Photographs of some monitoring locations are included at the end of this appendix.

Table 2.2.12: METEOROLOGY - SNOW CORE MEASUREMENTS (1985)

Date (1985)	Location	Snow Depth (cm)	Ice Thickness (cm)	Snow Volume (mL)	Water Equivalent Volume (mL)
Mar 6	RF-05	64.8	skim	2955	740
	RF-06	52.1	skim	2376	695
	RF-07	47.0	<2.5	2143	575
	RF-08	55.9	5.0	2549	675
	RF-10	36.8	3.8	1678	560
Mar 7	RF-01	68.6	7.6	3128	1030
	RF-02	47.0	2.5	2143	610
	RF-03	63.5	2.5	2896	830
	RF-04	63.5	7.6	2896	820
	RF-09	55.9	7.6	2549	485
	RF-11	45.7	12.5	2084	530
	RF-12	35.6	15 slush, 15 water	1623	435
	RF-13	63.5	7.6	2896	790
	RF-14	58.4	6.4	2663	630
	RF-15	61.0	5.0	2782	665
	RF-16	58.4	6.4	2663	785
	RF-17	55.9	2.5	2549	735
	RF-18	53.3	<2.5	2430	790
Mean		54.8		2500	688
Apr 4(1)	RF-01	32.0	-	1459	1020
	RF-02	16.9	-	770	-
	RF-03	30.1	-	1373	-
	RF-04	30.1	-	1373	-
	RF-05	30.8	-	1405	600
	RF-06	23.6	-	1076	-
	RF-07	17.0	-	775	-
	RF-08	25.5	-	1163	-
	RF-09	25.5	-	1163	430
	RF-10	11.4	-	520	-
	RF-11	16.7	-	762	540
	RF-12	11.2	-	511	-
	RF-13	30.1	-	1373	-
	RF-14	26.3	-	1199	-
	RF-15	28.9	-	1318	-
	RF-16	26.3	-	1199	760
	RF-17	25.5	-	1163	-
	RF-18	24.1	-	1099	-
Mean		24.0		1095	670(2)

Notes:

(1) Mixture of hard packed snow, slushy snow and ice

(2) Only five water equivalent measurements made

2.3.2 Dustfall

The dustfall sampling involved the collection of settleable particles from the atmosphere in open topped jars of 152 mm diameter and 460 mm height. Following an exposure period (typically 30 days) the contents of the jar were analyzed to determine the organic /mineral and soluble/insoluble fractions present. Three-month composites of the mineral (inorganic) fractions for each site were prepared and analyzed for various radionuclides. For the four sites (AQ-01 to AQ-04) located on the edge of the tailings area, the composites were analyzed for the following six radionuclides:

radium-226
thorium-228
thorium-230
thorium-232
lead-210
uranium

For the four sites (AQ-05 to AQ-08) located at various distances off the tailings, the composites were analyzed for only radium-226, thorium-230 and uranium.

The results of the dustfall analyses for each site are presented on Tables 2.3.1 to 2.3.8. Total dustfall measured during one month sampling for the four close-in sites ranged from 0.28 to 5.35 $g/m^2/30$ days with an average dustfall of 1.24 $g/m^2/30$ days. The organic content ranged from 42% to 86% with a mean organic content of 60%. With respect to radionuclide analyses, lead-210 activity levels per gram were the highest for the five parameters and ranged from 0.05 Bq/g for the spring composite at AQ-01 to 1.10 Bq/g for the fall composite at AQ-01. Uranium levels ranged from 0.07 ug/g for the summer composite at AQ-01 to 1.03 ug/g for the spring composite at AQ-02.

For the off-tailings sites the total dustfall measured during one month sampling ranged from 0.12 to 4.20 $g/m^2/30$ days with an average dustfall of

Table 2.3.1: AIR QUALITY - DUSTFALL ANALYSIS, SITE AQ-01 (1985)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	24 Jan	28 Feb	2 Apr	1 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	2 Apr	1 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	30 Oct
Duration (days)	35	33	29	30	28	35	33	28	28
Standard Analysis									
Total Fallout ($gm/m^2/30$ days)	0.58	0.63	1.25	2.09	2.52	0.61	0.42	2.4	0.64
Combustible Fallout ($gm/m^2/30$ days)	0.26	0.33	0.76	1.04	1.62	0.32	0.20	2.05	0.27
Organic Content (%)	45	52	61	50	64	52	48	85	42
Radionuclide Analysis (Inorganic Fraction)									
Composite Weight (gm)		1.11			2.24			0.94	
Ra-226 (Bq/g)		0.009 ± 0.009			0.007 ± 0.007			0.074 ± 0.021	
Th-228 (Bq/g)		<0.009			0.003 ± 0.003			<0.011	
Th-230 (Bq/g)		0.009 ± 0.009			<0.003			<0.011	
Th-232 (Bq/g)		<0.009			<0.003			<0.011	
Pb-210 (Bq/g)		<0.05			0.29 ± 0.06			0.96 ± 0.21	
Uranium (ug/g)		0.36			0.07			0.21	

Table 2.3.2: AIR QUALITY - DUSTFALL ANALYSIS, SITE AQ-02 (1985)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	24 Jan	28 Feb	ND	3 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	2 Apr		31 May	28 Jun	2 Aug	4 Sep	2 Oct	30 Oct
Duration (days)	35	33		28	28	35	33	28	28
Standard Analysis									
Total Fallout (gm/m^2/30 days)	0.52	0.64		2.70	2.73	0.62	0.40	1.44	0.65
Combustible Fallout (gm/m^2/30 days)	0.34	0.43		1.27	1.88	0.37	0.19	1.24	0.33
Organic Content (%)	65	67		47	69	60	48	86	51
Radionuclide Analysis (Inorganic Fraction)									
Composite Weight (gm)		0.39			2.54			0.73	
Ra-226 (Bq/g)		<0.026			0.024 ± 0.008			0.164 ± 0.054	
Th-228 (Bq/g)		<0.026			0.004			<0.014	
Th-230 (Bq/g)		<0.026			0.008 ± 0.004			0.041 ± 0.027	
Th-232 (Bq/g)		<0.026			0.004 ± 0.004			<0.014	
Pb-210 (Bq/g)		<0.013			0.12 ± 0.06			1.10 ± 0.27	
Uranium (ug/g)		1.03			0.08			0.14	

Note:

ND - Unit tipped over during month

Table 2.3.3: AIR QUALITY - DUSTFALL ANALYSIS, SITE AQ-03 (1985)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	24 Jan	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	1 Nov
Duration (days)	35	32	31	29	28	35	33	28	30
Standard Analysis									
Total Fallout (gm/m^2/30 days)	0.59	0.79	0.69	2.21	1.6	0.42	0.62	1.49	1.21
Combustible Fallout (gm/m^2/30 days)	0.32	0.59	0.47	1.04	0.72	0.28	0.38	1.20	0.52
Organic Content (%)	54	75	68	47	45	66	61	81	43
Radionuclide Analysis (Inorganic Fraction)									
Composite Weight (gm)		0.69			2.19			1.22	
Radionuclides in Inorganic Fraction									
Ra-226 (Bq/g)		<0.014			<0.005			0.098 ± 0.032	
Th-228 (Bq/g)		<0.014			0.005 ± 0.005			<0.008	
Th-230 (Bq/g)		<0.014			<0.005			<0.008	
Th-232 (Bq/g)		<0.014			<0.005			<0.008	
Pb-210 (Bq/g)		<0.07			0.19 ± 0.08			0.74 ± 0.16	
Uranium (ug/g)		0.14			0.18			0.57	

Table 2.3.4: AIR QUALITY - DUSTFALL ANALYSIS, SITE AQ-04 (1985)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	25 Jan	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	1 Nov
Duration (days)	34	32	31	29	28	35	33	28	30
Standard Analysis									
Total Fallout (gm/m^2/30 days)	0.43	0.74	1.03	0.93	1.72	5.35	0.28	1.0	1.66
Combustible Fallout (gm/m^2/30 days)	0.32	0.33	0.77	0.62	0.83	4.04	0.15	0.59	1.17
Organic Content (%)	74	45	75	67	48	76	54	59	70
Radionuclide Analysis (Inorganic Fraction)									
Composite Weight (gm)		0.78			2.51			1.03	
Ra-226 (Bq/g)		<0.013			0.020 ± 0.004			0.174 ± 0.058	
Th-228 (Bq/g)		<0.013			<0.004			0.010 ± 0.010	
Th-230 (Bq/g)		<0.013			0.004 ± 0.004			0.019 ± 0.010	
Th-232 (Bq/g)		<0.013			<0.004			<0.010	
Pb-210 (Bq/g)		<0.06			0.18 ± 0.07			0.87 ± 0.19	
Uranium (ug/g)		0.38			0.32			0.19	

Table 2.3.5: AIR QUALITY - DUSTFALL ANALYSIS, SITE AQ-05 (1985)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	26 Jan	28 Feb	2 Apr	1 May	31 May	28 Jun	2 Aug	No	2 Oct
Date Off	28 Feb	2 Apr	3 May	31 May	28 Jun	2 Aug	4 Sep	Sample	30 Oct
Duration (days)	33	33	31	30	28	35	33		28
Standard Analysis									
Total Fallout (gm/m^2/30 days)	0.63	1.13	1.99	1.94	2.62	2.24	1.37		0.80
Combustible Fallout (gm/m^2/30 days)	0.50	0.74	1.37	0.93	1.50	1.95	1.16		0.42
Organic Content (%)	79	65	69	48	57	87	85		53
Radionuclide Analysis (Inorganic Fraction)*									
Composite Weight (gm)		1.14			2.43			0.59	
Ra-226 (Bq/g)		<0.009			<0.004			0.169 ± 0.051	
Th-228 (Bq/g)		-			-			-	
Th-230 (Bq/g)		<0.009			<0.004			<0.017	
Th-232 (Bq/g)		-			-			-	
Pb-210 (Bq/g)		-			-			-	
Uranium (ug/g)		0.18			0.16			<0.17	

* analysis only for Ra-226, Th-230 and Uranium

Table 2.3.6: AIR QUALITY - DUSTFALL ANALYSIS, SITE AQ-06 (1985)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	24 Jan	28 Feb	2 Apr	3 May	31 May	28 Jun	2 Aug	4 Sep	3 Oct
Date Off	28 Feb	2 Apr	3 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	30 Oct
Duration (days)	35	33	32	28	28	35	33	28	28
Standard Analysis									
Total Fallout ($gm/m^2/30$ days)	0.40	0.42	1.09	2.18	3.11	2.07	2.42	0.89	1.15
Combustible Fallout ($gm/m^2/30$ days)	0.29	0.20	0.67	0.99	2.30	1.88	2.29	0.62	0.62
Organic Content (%)	72	48	61	46	74	91	95	70	54
Radionuclide Analysis (Inorganic Fraction)*									
Composite Weight (gm)		0.75			2.19			0.93	
Ra-226 (Bq/g)		<0.013			0.037 ± 0.009			0.086 ± 0.022	
Th-228 (Bq/g)		-			-			-	
Th-230 (Bq/g)		<0.013			<0.005			0.011 ± 0.011	
Th-232 (Bq/g)		-			-			-	
Pb-210 (Bq/g)		-			-			-	
Uranium (ug/g)		0.40			0.18			0.32	

* analysis only for Ra-226, Th-230 and Uranium

Table 2.3.7: AIR QUALITY - DUSTFALL ANALYSIS, SITE AQ-07 (1985)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	24 Jan	25 Feb	2 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	3 Oct
Date Off	25 Feb	1 Apr	3 May	31 May	28 Jun	2 Aug	4 Sep	3 Oct	5 Nov
Duration (days)	32	35	31	29	28	35	33	29	33
Standard Analysis									
Total Fallout (gm/m^2/30 days)	0.42	1.12	1.28	2.25	4.20	2.09	0.84	0.52	0.97
Combustible Fallout (gm/m^2/30 days)	0.25	0.64	0.80	1.00	2.97	1.88	0.66	0.41	0.53
Organic Content (%)	60	57	62	44	71	90	79	79	55
Radionuclide Analysis (Inorganic Fraction)*									
Composite Weight (gm)		1.13			2.69			0.73	
Ra-226 (Bq/g)		<0.009			<0.004			0.096 ± 0.027	
Th-228 (Bq/g)		-			-			-	
Th-230 (Bq/g)		<0.009			<0.004			<0.014	
Th-232 (Bq/g)		-			-			-	
Pb-210 (Bq/g)		-			-			-	
Uranium (ug/g)		0.27			0.15			0.14	

* analysis only for Ra-226, Th-230 and Uranium

Table 2.3.8: AIR QUALITY - DUSTFALL ANALYSIS, SITE AQ-08 (1985)

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	25 Jan	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	1 Nov
Duration (days)	34	32	31	29	28	35	33	28	30
Standard Analysis									
Total Fallout (gm/m^2/30 days)	0.46	0.95	0.12	2.46	2.75	2.04	2.44	2.26	0.58
Combustible Fallout (gm/m^2/30 days)	0.37	0.62	0.09	1.08	1.06	1.57	2.29	1.82	0.25
Organic Content (%)	80	65	75	44	39	77	94	81	43
Radionuclide Analysis (Inorganic Fraction)*									
Composite Weight (gm)		0.45			3.54			0.92	
Ra-226 (Bq/g)		<0.022			0.006 ± 0.006			0.065 ± 0.022	
Th-228 (Bq/g)		-			-			-	
Th-230 (Bq/g)		<0.022			<0.003			0.033 ± 0.022	
Th-232 (Bq/g)		-			-			-	
Pb-210 (Bq/g)		-			-			-	
Uranium (ug/g)		1.11			0.14			0.76	

* analysis only for Ra-226, Th-230 and Uranium

1.55 g/m^2/30 days. The organic content ranged from 39% to 95% with a mean organic content of 67%. With respect to radionuclide analyses, radium-226 activity levels per gram were equal to or higher than the levels for thorium-230 and ranged from less than 0.004 Bq/g for the summer composites at AQ-05 and AQ-07 to 0.169 Bq/g for the fall composite at AQ-05. Uranium levels ranged from 0.14 ug/g for the fall composite at AQ-07 and summer composite at AQ-08 to 1.11 ug/g for the spring composite at AQ-08.

2.3.3 Suspended Particulate Matter (SPM)

Suspended particulate sampling involves drawing a known volume of air through a filter over a specified period to determine the concentration of total suspended particulate matter (TSP) in air. The samplers were operated for one continuous 24 hour period approximately once every six days, based on the schedule of the National Air Pollution Surveillance (NAPS) network. Because the samplers were powered by portable generators some deviation from the NAPS schedule did occur.

For this study two particle size ranges were collected at each site. Sampling units 1 and 3 at AQ-09 and AQ-10 respectively, were equipped with a selective size inlet head which only permitted particles of less than 10 microns in aerodynamic diameter to be collected on the filter. This size particle is representative of the respirable fraction of TSP.

Sampling units 2 and 4 at AQ-09 and AQ-10 respectively, were operated in the standard sampling configuration which permitted particles typically smaller than 50 micron in aerodynamic diameter to be collected on the filter.

The samples were weighed after exposure to determine the SPM loading. Composites of each month's samples were prepared for radionuclide analysis. A summary of results for each sampler at AQ-09 and AQ-10 is presented on Tables 2.3.9 to 2.3.12. Station AQ-09 was located on the tailings while station AQ-10 was located some 250 metres west of the tailings.

Table 2.3.9: AIR QUALITY - RESPIRABLE SUSPENDED PARTICULATE MATTER ANALYSIS SUMMARY, SITE AQ-09 UNIT 1 (1985)

	Jan-Feb(1)	Mar	Apr	May	Jun#1(2)	Jun#2(2)	Jul#1(2)	Jul#2(2)	Aug	Sep	Oct
No. of Samples	6	5	5	5	5		6		5	4	4
Standard Analysis											
Geometric Mean	5.8	7.6	6.5	2.3	11.0		11.0		12.1	13.2	8.0
Max. (ug/m^3)	7.2	27.1	17.0	11.4	23.2		25.5		13.9	26.7	14.6
Min. (ug/m^3)	3.6	3.1	2.9	0.4	5.0		4.6		10.5	4.3	3.1
Radionuclide Analysis											
Composite Weight(g)	0.030	0.061	0.0677	0.0333	0.0509	0.0509	0.0634	0.0634	0.0970	0.1092	0.0706
Ra-226(Bq/g)	3.0±1.3	0.7±0.5	1.3±0.6	2.1±0.9	3.5±0.6	1.4±0.2	4.3±0.8	0.8±0.2	1.3±0.2	0.4±0.2	1.1±0.3
Th-228(Bq/g)	<0.3	0.2±0.2	0.1±0.1	<0.3	<0.2	1.0±0.4	<0.2	1.7±0.2	<0.1	<0.1	0.1±0.1
Th-230(Bq/g)	2.3±1.3	0.5±0.3	0.9±0.4	<0.3	0.8±0.4	1.2±0.4	0.3±0.3	1.6±0.2	0.5±0.3	<0.1	0.4±0.3
Th-232(Bq/g)	<0.3	0.2±0.2	<0.1	<0.3	<0.2	0.4±0.2	<0.2	1.4±0.2	<0.1	<0.1	<0.1
Pb-210(Bq/g)	30±13	30±8	6±3	48±6	28±2	28±4	38±11	33±3	22±4	27±2	48±3
U(ug/g)	150	62	71	72	94	104	175	129	28	11	195

Note:

Radionuclide concentrations based on total activity of the filter divided by the composite weight.

(1) Jan-Feb sample was halved and sent for radionuclide analysis to two laboratories, sample contaminated by check lab preventing check analysis

(2) Sample was halved and radionuclide analysis carried out by two laboratories.

Table 2.3.10: AIR QUALITY - TOTAL SUSPENDED PARTICULATE MATTER ANALYSIS SUMMARY, SITE AQ-09 UNIT 2 (1985)

	Jan-Feb(1)	Mar	Apr	May	Jun#1(2)	Jun#2(2)	Jul#1(2)	Jul#2(2)	Aug	Sep	Oct
No. of Samples	6	5	5	5	5		6		3	4	3
Standard Analysis											
Geometric Mean	8.3	10.0	11.2	7.9	22.1		17.3		17.2	16.6	10.3
Max. (ug/m^3)	10.0	33.9	24.3	21.4	51.6		38.5		18.9	38.2	25.4
Min. (ug/m^3)	7.4	5.5	5.6	3.4	5.3		9.1		15.9	6.9	4.7
Radionuclide Analysis											
Composite Weight(g)	0.048	0.087	0.114	0.086	0.125	0.125	0.111	0.111	0.154	0.152	0.043
Ra-226(Bq/g)	1.7±0.8	0.2±0.2	0.4±0.4	2.1±0.5	2.8±0.6	1.0±0.1	5.0±0.5	0.5±0.1	0.6±0.1	0.3±0.1	0.5±0.2
Th-228(Bq/g)	<0.2	<0.1	0.3±0.2	0.1±0.1	0.1±0.1	0.4±0.2	<0.1	1.0±0.1	<0.1	0.1±0.1	<0.2
Th-230(Bq/g)	1.0±0.6	0.5±0.2	0.5±0.3	0.2±0.2	0.7±0.3	0.3±0.2	0.5±0.4	1.1±0.1	0.2±0.1	0.1±0.1	<0.2
Th-232(Bq/g)	0.2±0.2	0.1±0.1	0.2±0.2	0.1±0.1	<0.1	<0.1	0.2±0.2	0.9±0.1	<0.1	<0.1	<0.2
Pb-210(Bq/g)	6±4	14±5	2±2	18±2	17±2	10±1.6	10±6	27±2	19±3	23±1	53±7
U(ug/g)	125	69	58	36	47	53	145	153	19	11	149

Note:

Radionuclide concentrations based on total activity of the filter divided by the composite weight.

(1) Jan-Feb sample was halved and sent for radionuclide analysis to two laboratories, sample contaminated by check lab preventing check analysis

(2) Sample was halved and radionuclide analysis carried out by two laboratories.

Table 2.3.11: AIR QUALITY - RESPIRABLE PARTICULATE MATTER ANALYSIS SUMMARY, SITE AQ-10 UNIT 3 (1985)

	Jan-Feb	Mar-Apr	May	Jun	Jul	Aug	Sep	Oct
No. of Samples	5	4	5	5	5	5	3	4
Standard Analysis								
Geometric Mean	7.9	7.7	2.0	7.9	9.5	10.4	16.1	6.0
Max. (ug/m^3)	10.0	24.5	11.3	23.5	23.6	11.6	26.3	13.5
Min. (ug/m^3)	5.3	1.9	0.6	4.2	3.5	8.2	10.1	3.0
Radionuclide Analysis								
Composite Weight(g)	0.530	0.055	0.028	0.080	0.087	0.797	0.820	0.051
Ra-226(Bq/g)	0.06±0.02	0.5±0.2	0.4±0.4	<0.1	0.2±0.1	0.06±0.03	<0.01	<0.2
Th-228(Bq/g)	<0.02	0.4±0.4	0.7±0.7	<0.1	<0.1	<0.01	<0.01	<0.2
Th-230(Bq/g)	0.04±0.04	0.7±0.4	0.7±0.7	0.1±0.1	<0.1	0.04±0.3	<0.01	<0.2
Th-232(Bq/g)	<0.02	0.2±0.2	0.7±0.7	<0.1	0.1±0.1	<0.01	<0.01	<0.2
Pb-210(Bq/g)	0.8±0.4	<2	53±7	21±2	24±5	2.5±0.5	3.4±0.2	51±4
U(ug/g)	3.0	22	32	59	39	2.6	2.8	51

Note:

Radionuclide concentrations based on total activity of the filter divided by the composite weight.

Table 2.3.12: AIR QUALITY - TOTAL SUSPENDED PARTICULATE MATTER ANALYSIS SUMMARY, SITE AQ-10 UNIT 4 (1985)

	Jan-Feb	Mar-Apr	May	Jun	Jul	Aug	Sep	Oct
No. of Samples	5	4	5	5	5	5	3	4
Standard Analysis								
Geometric Mean	8.8	15.6	5.6	19.7	14.0	13.6	23.4	7.5
Max. (ug/m^3)	10.9	39.7	18.4	37.4	30.2	15.2	48.8	14.1
Min. (ug/m^3)	6.3	5.9	2.1	11.9	6.6	12.4	8.1	4.0
Radionuclide Analysis								
Composite Weight(g)	0.080	0.104	0.073	0.210	0.087	0.117	0.157	0.069
Ra-226(Bq/g)	0.5±0.1	0.4±0.2	0.5±0.3	0.3±0.1	0.2±0.1	0.3±0.2	<0.1	<0.1
Th-228(Bq/g)	<0.1	<0.1	0.1±0.1	<0.05	<0.1	0.1±0.1	<0.1	<0.1
Th-230(Bq/g	0.6±0.4	0.3±0.2	0.4±0.3	0.2±0.1	0.1±0.1	0.3±0.2	<0.1	0.4±0.3
Th-232(Bq/g)	<0.1	<0.1	0.3±0.3	<0.05	<0.1	0.2±0.1	0.1±0.1	0.1±0.1
Pb-210(Bq/g)	2±2	<0.1	25±3	8.1±1.0	29±5	27±3	16±1	39±3
U(ug/g)	32	19	26	32	42	26	19	70

Note:

Radionuclide concentrations based on total activity of the filter divided by the composite weight.

For the on-tailings site (AQ-09) the mean monthly total SPM levels ranged from 7.9 ug/m^3 in May to 22.1 ug/m^3 in June. The overall range in total SPM levels was from 3.4 ug/m^3 to 51.6 ug/m^3. The mean monthly respirable SPM levels (<10 microns) ranged from 2.3 ug/m^3 in May to 13.2 ug/m^3 in September. The overall range in respirable SPM levels was from 0.4 ug/m^3 to 27.1 ug/m^3. In a comparison of the respirable and total suspended particulate matter concentration measured for the same periods by units 1 and 2 respectively, the mean ratio of respirable SPM to total SPM was 0.61 and ranged from a low of 0.06 to 0.87. Three ratios greater than 1.0 were not included in this average.

With respect to radionuclide analyses, also presented on Table 2.3.9 and 2.3.10, lead-210 activity levels per gram were the highest of the five parameters measured and ranged from 2 Bq/g to 53 Bq/g. Uranium levels ranged from 11 ug/g to 195 ug/g.

For the off-tailings site (AQ-10) the mean monthly total SPM levels ranged from 7.5 ug/m^3 in October to 23.4 ug/m^3 in September. The overall range in total SPM levels was from 2.1 to 48.8 ug/m^3. The mean monthly respirable SPM levels (<10 microns) ranged from 2.0 ug/m^3 in May to 16.1 ug/m^3 in September. The overall range in respirable SPM levels was from 0.6 ug/m^3 to 26.3 ug/m^3. In a comparison of the respirable and total suspended particulate matter concentrations measured for the same periods by units 3 and 4 respectively, the mean ratio of respirable SPM to total SPM was 0.61 and ranged from a low of 0.22 to 0.96. Four ratios greater than 1.0 were not included in this average.

With respect to radionuclide analysis, also presented on Tables 2.3.11 and 2.3.12, lead-210 activity levels per gram were the highest of the five parameters measured and ranged from <0.1 Bq/g to 53 Bq/g. Uranium levels ranged from 2.6 ug/g to 70 ug/g.

Data sets 2.3.1 to 2.3.4 provide summaries of the daily suspended particulate matter sampling results for units 1 to 4.

2.4 Radioactivity

2.4.1 Program Description

The measurements of radioactivity described in this section pertain to the ambient radon monitoring carried out in the immediate vicinity of the tailings, the determination of radon exhalation rates from the surface of the tailings and documentation of the gamma radiation levels over the surface of tailings.

2.4.2 Radon Monitoring

Ambient radon levels in the immediate vicinity of the tailings were measured using two types of monitoring systems. The first system employed R.A.D. passive electrostatically-enhanced monitors. Because of their high sensitivity these units were used to monitor radon levels over the short-term, typically one month. The second system employed Terradex track-etch radon detectors. Because of their lower sensitivity these detectors were used to monitor radon levels over the long-term, typically three months. For each program a set of eight monitors was used.

The locations of the monitors are shown on Figure 2.1 For the short-term program four sites RD-01 to RD-04 were located at the edge of the tailings while the other four RD-05 to RD-08 sites were located a short distance off the tailings (<100 m). For the long-term program four sites (RD-01 to RD-04) were common with the short-term program at the edge of tailings while the other four sites (RD-09 to RD-12) were located some distance off the tailings (>100 m).

The results for the short-term program are presented on Tables 2.4.1 to 2.4.8. The radon levels for the four sites at the edge of the tailings (RD-01 to RD-04) ranged from less than 0.002 Bq/L to 0.039 Bq/L with an average level of 0.019 Bq/L. The radon levels for the sites a short distance off the tailings

Table 2.4.1: RADIOACTIVITY - SHORT-TERM RADON CONCENTRATIONS, SITE RD-01

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	25 Jan	28 Feb	2 Apr	1 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	2 Apr	1 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	30 Oct
Days Exposed	34	33	29	30	28	35	33	28	28
Radon (Bq/L)	LDL	LDL	0.025	0.009	0.017	0.021	0.017	0.006	0.018
(pCi/L)	LDL	LDL	0.67	0.24	0.46	0.58	0.47	0.15	0.49

Table 2.4.2: RADIOACTIVITY - SHORT-TERM RADON CONCENTRATIONS, SITE RD-02

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	24 Jan	28 Feb	2 Apr	3 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	2 Apr	3 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	30 Oct
Days Exposed	35	33	31	30	28	35	33	28	28
Radon (Bq/L)	0.004	LDL	0.016	0.013	0.018	0.020	0.037	0.020	0.018
(pCi/L)	0.12	LDL	0.42	0.36	0.49	0.55	1.00	0.54	0.49

Notes:

LDL - Less than detection limit of 0.002 Bq/L or 0.05 pCi/L.

All measurements made using a passive, electrostatically-enhanced monitor.

Table 2.4.3: RADIOACTIVITY - SHORT-TERM RADON CONCENTRATIONS, SITE RD-03

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	24 Jan	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	1 Nov
Days Exposed	35	32	31	29	28	35	33	28	30
Radon (Bq/L)	0.026	LDL	0.016	0.010	0.013	0.016	0.016	0.012	0.009
(pCi/L)	0.69	LDL	0.42	0.26	0.35	0.42	0.44	0.32	0.24

Table 2.4.4: RADIOACTIVITY - SHORT-TERM RADON CONCENTRATIONS, SITE RD-04

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	25 Jan	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	1 Nov
Days Exposed	34	32	31	29	28	35	33	28	30
Radon (Bq/L)	0.017	0.014	0.019	0.032	0.027	0.037	0.039	0.014	0.025
(pCi/L)	0.46	0.39	0.50	0.87	0.73	1.00	1.04	0.39	0.68

Notes:

LDL - Less than detection limit of 0.002 Bq/L or 0.05 pCi/L.

All measurements made using a passive, electrostatically-enhanced monitor.

Table 2.4.5: RADIOACTIVITY - SHORT-TERM RADON CONCENTRATIONS, SITE RD-05

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	25 Jan	28 Feb	2 Apr	1 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	2 Apr	1 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	30 Oct
Days Exposed	34	33	29	30	28	35	33	28	28
Radon (Bq/L)	0.014	0.003	0.034	0.040	0.012	0.007	0.015	ND	0.021
(pCi/L)	0.38	0.07	0.91	1.08	0.32	0.20	0.40	ND	0.56

Table 2.4.6: RADIOACTIVITY - SHORT-TERM RADON CONCENTRATIONS, SITE RD-06

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	24 Jan	28 Feb	2 Apr	3 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	2 Apr	3 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	30 Oct
Days Exposed	35	33	31	28	28	35	33	28	28
Radon (Bq/L)	0.010	LDL	LDL	0.006	LDL	0.006	0.013	0.008	0.026
(pCi/L)	0.26	LDL	LDL	0.17	LDL	0.15	0.35	0.21	0.69

Notes:

LDL - Less than detection limit of 0.002 Bq/L or 0.05 pCi/L.
ND - No Data
All measurements made using a passive, electrostatically-enhanced monitor.

Table 2.4.7: RADIOACTIVITY - SHORT-TERM RADON CONCENTRATIONS, SITE RD-07

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	25 Jan	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	5 Nov
Days Exposed	34	32	31	29	28	35	33	28	34
Radon (Bq/L)	LDL	LDL	0.004	0.007	0.010	0.010	0.010	LDL	0.006
(pCi/L)	LDL	LDL	0.11	0.18	0.28	0.27	0.27	LDL	0.15

Table 2.4.8: RADIOACTIVITY - SHORT-TERM RADON CONCENTRATIONS, SITE RD-08

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Date On	24 Jan	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct
Date Off	28 Feb	1 Apr	2 May	31 May	28 Jun	2 Aug	4 Sep	2 Oct	1 Nov
Days Exposed	35	32	31	29	28	35	33	28	30
Radon (Bq/L)	0.012	LDL	0.015	0.019	0.017	0.015	0.021	0.005	LDL
(pCi/L)	0.33	LDL	0.41	0.52	0.45	0.40	0.56	0.13	LDL

Notes:

LDL - Less than detection limit of 0.002 Bq/L or 0.05 pCi/L.

All measurements made using a passive, electrostatically-enhanced monitor.

Table 2.4.9: RADIOACTIVITY - LONG-TERM RADON CONCENTRATIONS, SITE RD-01

	Monitoring Period		
	Feb - Apr	May - Jul	Aug - Oct
Date On	25 Jan	1 May	8 Aug
Date Off	1 May	8 Aug	30 Oct
Days Exposed	96	99	83
Radon (Bq/L)	0.011	0.040	0.034
(pCi/L)	0.30	1.09	0.91

Table 2.4.10: RADIOACTIVITY - LONG-TERM RADON CONCENTRATIONS, SITE RD-02

	Monitoring Period		
	Feb - Apr	May - Jul	Aug - Oct
Date On	24 Jan	3 May	8 Aug
Date Off	3 May	8 Aug	30 Oct
Days Exposed	99	97	83
Radon (Bq/L)	0.018	0.037	0.047
(pCi/L)	0.49	1.01	1.27

Notes:

All measurements made using a passive, alpha-sensitive plastic detector.

Table 2.4.11: RADIOACTIVITY - LONG-TERM RADON CONCENTRATIONS, SITE RD-03

	Monitoring Period		
	Feb - Apr	May - Jul	Aug - Oct
Date On	24 Jan	2 May	8 Aug
Date Off	2 May	8 Aug	1 Nov
Days Exposed	98	98	85
Radon (Bq/L)	0.025	0.041	0.059
(pCi/L)	0.67	1.10	1.59

Table 2.4.12: RADIOACTIVITY - LONG-TERM RADON CONCENTRATIONS, SITE RD-04

	Monitoring Period		
	Feb - Apr	May - Jul	Aug - Oct
Date On	25 Jan	2 May	8 Aug
Date Off	2 May	8 Aug	1 Nov
Days Exposed	97	98	85
Radon (Bq/L)	0.008	0.051	0.049
(pCi/L)	0.22	1.38	1.33

Notes:

All measurements made using a passive, alpha-sensitive plastic detector.

Table 2.4.13: RADIOACTIVITY - LONG-TERM RADON CONCENTRATIONS, SITE RD-09

	Monitoring Period		
	Feb - Apr	May - Jul	Aug - Oct
Date On	25 Jan	1 May	8 Aug
Date Off	1 May	8 Aug	30 Oct
Days Exposed	96	99	83
Radon (Bq/L)	0.006	0.017	0.013
(pCi/L)	0.17	0.47	0.35

Table 2.4.14: RADIOACTIVITY - LONG-TERM RADON CONCENTRATIONS, SITE RD-10

	Monitoring Period		
	Feb - Apr	May - Jul	Aug - Oct
Date On	25 Jan	3 May	8 Aug
Date Off	3 May	8 Aug	1 Nov
Days Exposed	98	97	85
Radon (Bq/L)	0.009	0.013	0.030
(pCi/L)	0.25	0.35	0.81

Notes:

All measurements made using a passive, alpha-sensitive plastic detector.

Table 2.4.15: RADIOACTIVITY - LONG-TERM RADON CONCENTRATIONS, SITE RD-11

	Monitoring Period		
	Feb - Apr	May - Jul	Aug - Oct
Date On	24 Jan	2 May	8 Aug
Date Off	2 May	8 Aug	5 Nov
Days Exposed	98	98	89
Radon (Bq/L)	0.005	0.017	0.014
(pCi/L)	0.14	0.45	0.38

Table 2.4.16: RADIOACTIVITY - LONG-TERM RADON CONCENTRATIONS, SITE RD-12

	Monitoring Period			
	Feb - Apr	May - Jul	Aug - Oct	Control*
Date On	25 Jan	2 May	8 Aug	
Date Off	2 May	8 Aug	4 Nov	
Days Exposed	97	98	88	
Radon (Bq/L)	0.006	0.016	0.023	0.008
(pCi/L)	0.17	0.42	0.61	0.22

Notes:

All measurements made using a passive, alpha-sensitive plastic detector.

* Control kept with other detectors but not exposed in field or removed from packaging during February to October monitoring period.

(RD-05 to RD-08) ranged from 0.003 Bq/L to 0.040 Bq/L with an average level of 0.014 Bq/L.

The results for the long-term program are presented on Tables 2.4.9 to 2.4.16. The radon levels for the four sites at the edge of the tailings (RD-01 to RD-04) ranged from 0.008 Bq/L to 0.059 Bq/L with an average level of 0.035 Bq/L. The radon levels for the sites some distance off the tailings (RD-09 to RD-12) ranged from 0.005 Bq/L to 0.030 Bq/L with an average level of 0.014 Bq/L

2.4.3 Radon Exhalation

Radon exhalation rates from the surface of the tailings were determined using an accumulation technique whereby the change in radon concentration within a 23 litre collection chamber in contact with the emanating surface was measured over various time intervals. Measurements of the radon levels in the chamber were made using alphaMETER-400 integrating radon meters. A discussion of the theory is presented in Section 5.7.2 of the NUTP research report on Monitoring of Layered Uranium Tailings - Phase I May 1985.

The radon exhalation rates measured on the Lacnor tailings at the sites shown on Figure 2.1 are summarized on Table 2.4.17.

The exhalation rates ranged from a low of 0.0076 Bq/m^2/s in March on the surface of the ice to 6.67 Bq/m^2/s in June on the damp unvegetated tailings surface. For the winter sampling the exhalation rates were measured on the surface of the frozen tailings. To carry out the sampling 35 to 70 cm of snow and 2 to 8 cm of ice were removed from the site to expose the tailings surface. For the spring and summer sampling the exhalation rates were measured for a variety of tailings conditions including dry, damp, saturated, water covered, vegetated and non-vegetated.

2.4.4 Surface Gamma

During June and July a comprehensive surface gamma radiation survey of the

Table 2.4.17: RADIOACTIVITY - RADON EXHALATION (1985)

Site	Date	Surface Gamma (μR/h)	Exhalation Rate (Bq/m^2/s)	Comments
RF-01	7 March	110	0.253	tailings damp, soft, swamp muck
	14 June	220	0.190	tailings damp, no vegetation
RF-02	7 March	250	0.0466	on frozen surface
	14 June	230	0.307	vegetated surface
RF-03	7 March	265	0.0288	on frozen surface
	14 June	280	1.10	vegetated surface
RF-04	7 March	350	1.52	on frozen surface
	14 June	260	0.988	vegetated surface
RD-05	7 March	70	0.0114	tailings dry
	13 June	280	0.636	moss and grass cover
	13 June	280	0.915	moss and grass cover
RF-06	6 March	220	0.0437	on frozen dry surface
	13 June	240	0.657	moss and grass cover
	13 June	240	0.462	moss and grass cover
RF-07	6 March	340	0.378	on frozen dry surface
	27 May		0.544	dry surface
RF-08	6 March	240	0.290	tailings damp, soft under ice
	27 May		0.198	dry surface
RF-09	6 March	48	0.715	on frozen surface
	27 May		0.257	damp surface
RF-10	6 March	250	0.0076	on surface of ice
	6 March		0.0135	ice removed
RF-10a	6 March		0.104	no ice
RF-11	27 May		0.0752	surface covered with 25 mm water
RF-11a	27 May		0.114	surface saturated, no vegetation
RF-13	7 March	175	0.288	on damp surface
	13 June	220	0.171	surface moist, no vegetation
RF-14	7 March	220	0.0089	on dry, hard sandy surface
	12 June	280	0.841	surface damp, no vegetation
RF-15	12 June	220	1.93	surface damp
RF-16	7 March	240	0.190	on soft mushy surface
	12 June	320	6.67	surface damp, no vegetation
RF-17	7 March	355	0.258	on frozen dry surface
	12 June	355	1.45	surface damp, no vegetation

Table 2.4.17 continued

Site	Date	Surface Gamma (μR/h)	Exhalation Rate (Bq/m^2/a)	Comments
RF-18	7 March	310	0.252	on frozen dry surface
	12 June	220	0.836	surface dry, moss covered
RF-19	26 June	800	4.96	vegetated, dry surface
RF-19a	26 June	800	0.951	vegetated, dry surface
RF-20	14 June	190	0.0134	surface saturated
RF-21	12 July	360	1.70	sparce grass cover
RF-22	12 July	840	0.566	dead grass removed, peat underneath
RF-23	12 July	790	0.668	sprigs of grass
RF-24	12 July	700	1.58	dry, moss covered surface
RF-25	12 July	550	0.578	dry, bare surface

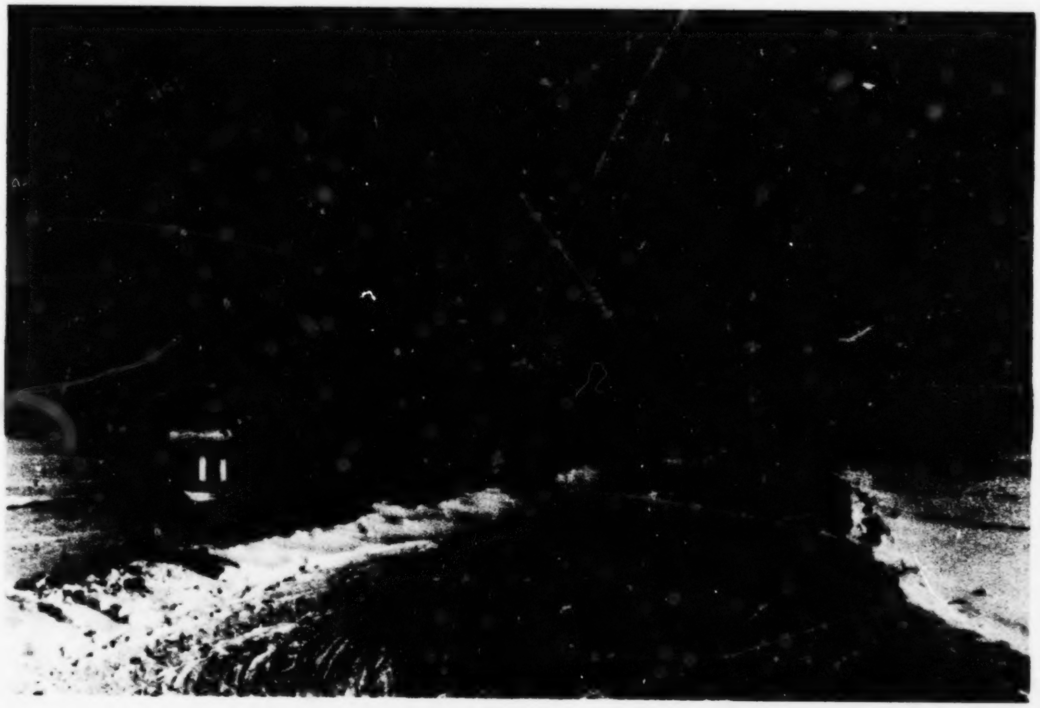
tailings area was carried out. To survey the area, measurements of gamma radiation levels were taken at the surface and waist height (approximately 1 metre) on a 30 m x 30 m grid applied over the site.

Measurements were taken using an Eberline PRM-7 meter. The survey meter had been calibrated using a standard radium-226 source.

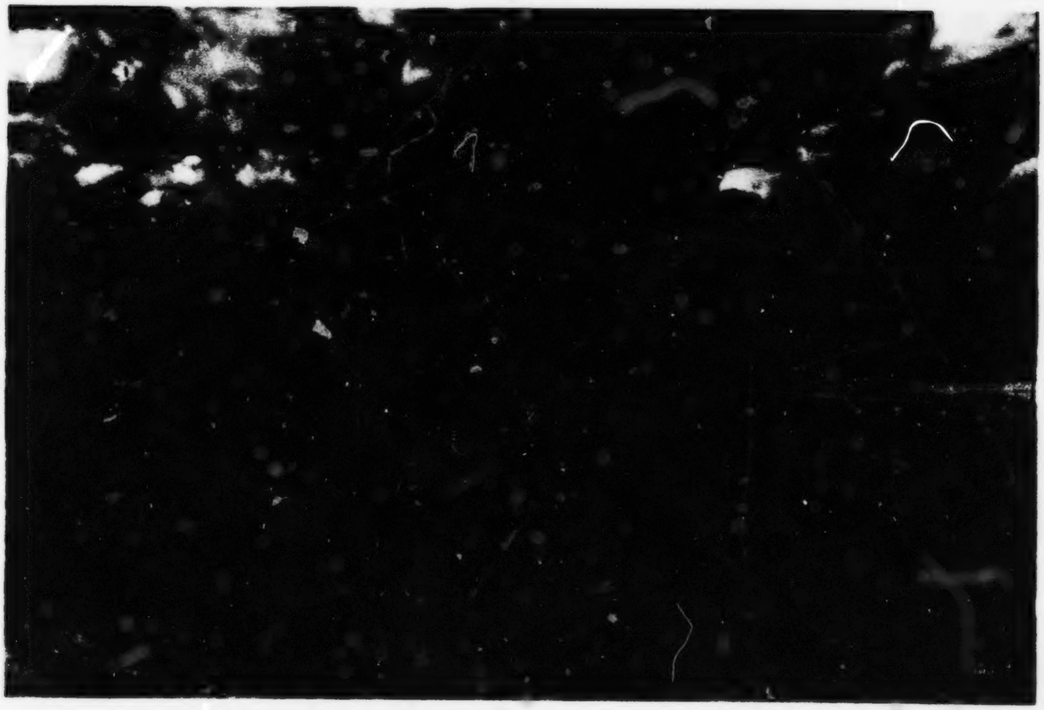
The results of the surface gamma survey are presented on Figure 2.2.

The contact gamma levels on the tailings range from a low of 30 uR/h to a high of 1100 uR/h. The higher gamma levels (>500 uR/h) were found in the eastern third of the site with several separate areas supporting gamma levels in excess of 1000 uR/h (1 mR/h). Few measurements were taken off the tailings because of limited access. However for the areas measured the gamma levels dropped quickly off once off the actual tailings. The physical appearance of the tailings provided little indication of anticipated gamma levels, that is to say that the levels were not limited to one specific type of physical appearance (ie. sandy, unvegetated, grass-covered etc).

REPRESENTATIVE
PHOTOGRAPHS



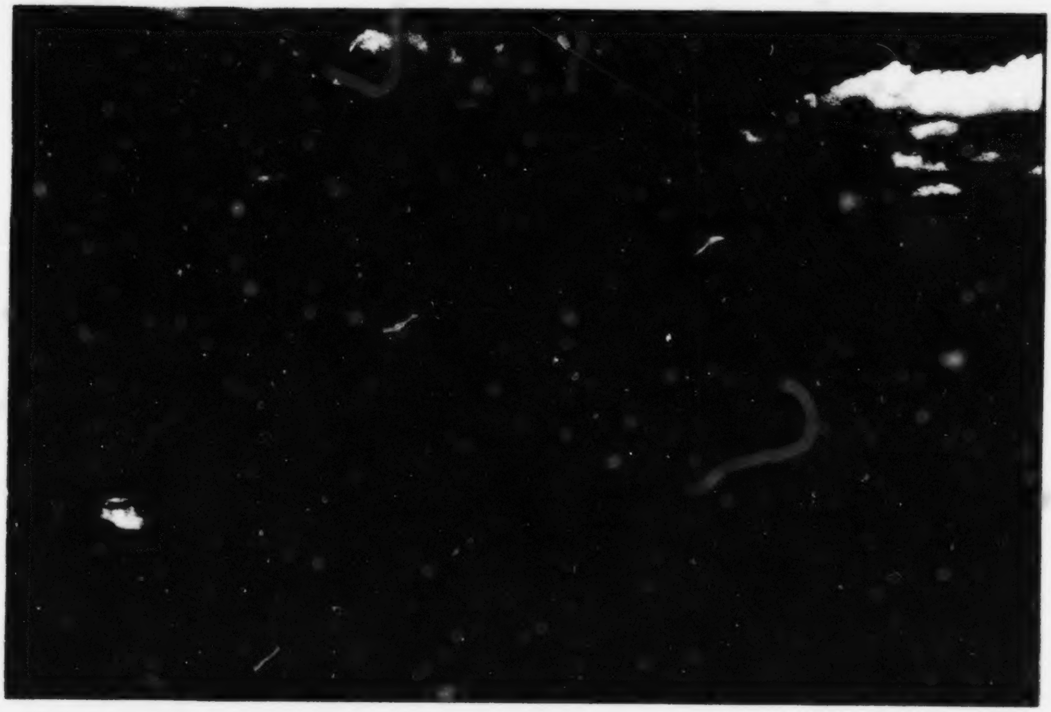
METEOROLOGICAL MT-01 - LOOKING SOUTH



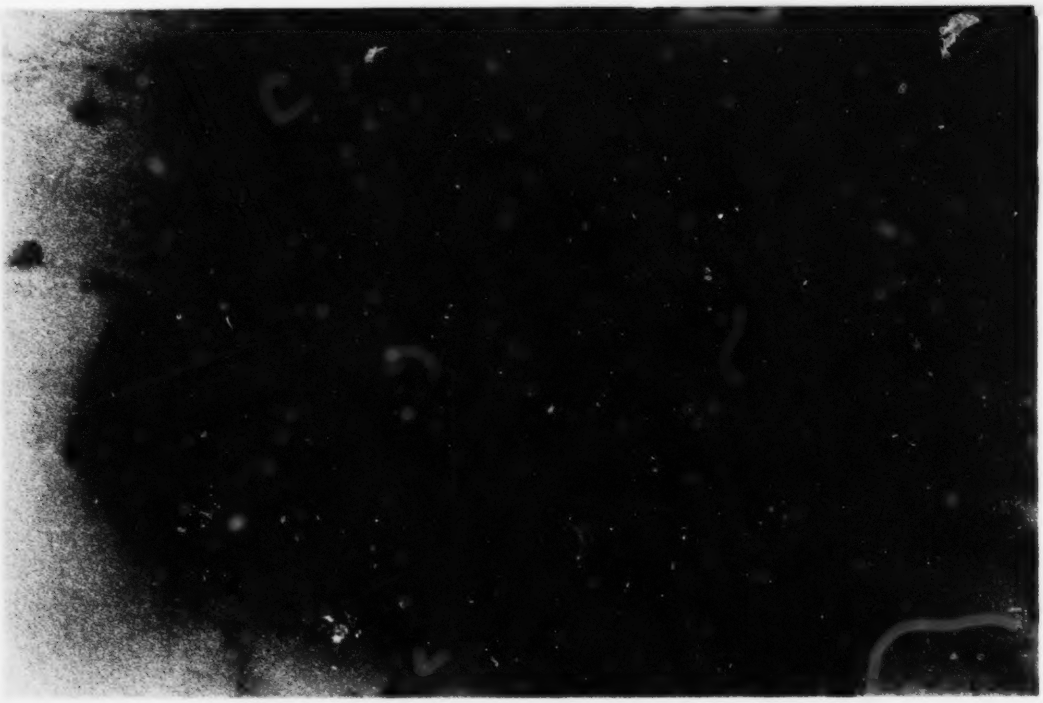
METEOROLOGICAL STATION MT-01 - LOOKING NORTHEAST

- 10 m tower with wind speed/direction and temperature sensors Sacramento precipitation gauge, evaporation pan, high volume air samplers

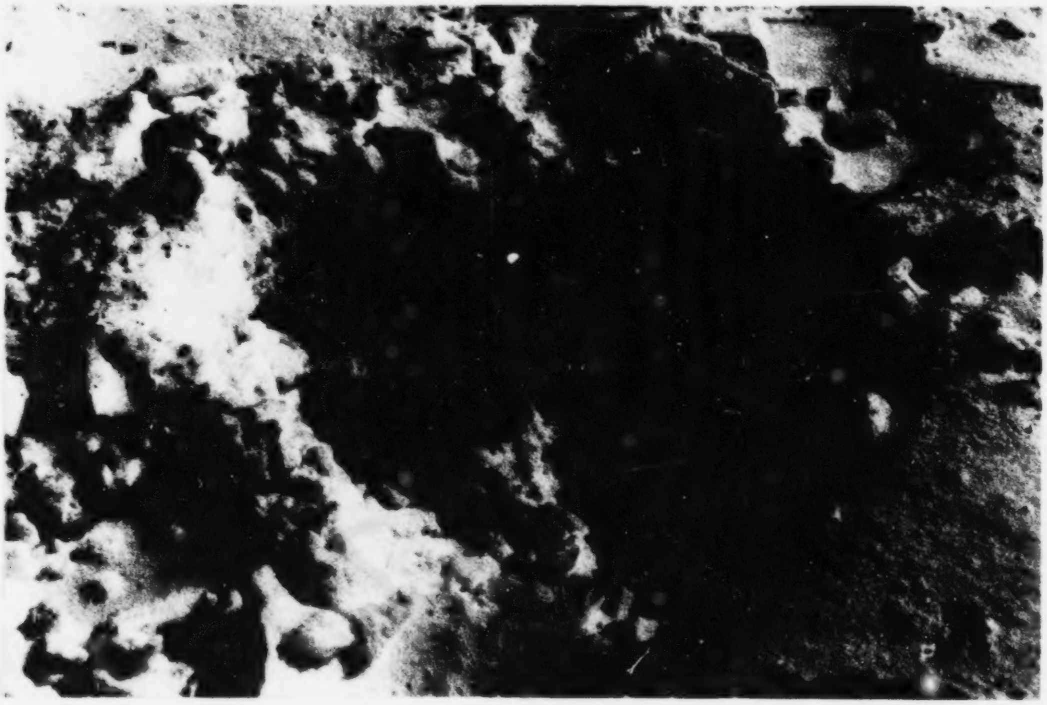
SITE AQ-04, RD-04 - LOOKING NORTH
- DUSTFALL JAR AND TWO TYPES OF RADON MONITORS



SITE AQ-04, RD-04 - LOOKING SOUTHEAST



RADON FLUX LOCATION RF-17
- radon accumulator and snow core sampler



RADON ACCUMULATOR

MAIN EAST-WEST GRID FOR GAMMA SURVEY AND RADON FLUX MEASUREMENTS

STAKES DENOTE RADON FLUX LOCATIONS

DATA SHEETS

FOR

SUSPENDED PARTICULATE

MATTER SAMPLERS

DATA SHEET 1 - Unit 1 Station AQ-09

LACNOR SUSPENDED PARTICULATE MATTER DATA SUMMARY

STATION	UNIT	DATE ON	DATE OFF	DURATION (HR)	NET WEIGHT (G)	SPM (UG/M3)
AQ-09	1	850125	850126	24.0	0.0060	3.6
AQ-09	1	850131	850201	25.7	0.0140	7.2
AQ-09	1	850206	850207	25.5	0.0100	5.7
AQ-09	1	850212	850213	23.6	0.0110	6.8
AQ-09	1	850218	850219	24.0	0.0120	7.3
AQ-09	1	850224	850225	23.0	0.0080	5.1
AQ-09	1	850301	850302	23.0	0.0120	7.4
AQ-09	1	850307	850308	12.0	0.0230	27.1
AQ-09	1	850314	850315	23.3	0.0050	3.1
AQ-09	1	850320	850321	22.7	0.0080	5.1
AQ-09	1	850325	850326	23.0	0.0130	8.0
AQ-09	1	850401	850402	16.5	0.0040	3.4
AQ-09	1	850408	850409	23.5	0.0120	7.4
AQ-09	1	850412	850413	25.0	0.0170	9.7
AQ-09	1	850419	850420	24.0	0.0296	17.0
AQ-09	1	850425	850426	24.5	0.0051	2.9
AQ-09	1	850501	850502	24.0	0.0028	1.6
AQ-09	1	850507	850508	24.5	0.0058	3.3
AQ-09	1	850513	850514	22.5	0.0006	0.4
AQ-09	1	850517	850518	21.8	0.0042	2.6
AQ-09	1	850524	850525	24.0	0.0199	11.4
AQ-09	1	850530	850531	22.0	0.0372	23.2
AQ-09	1	850613	850614	24.5	0.0089	5.0
AQ-09	1	850619	850620	23.0	0.0112	7.3
AQ-09	1	850624	850625	24.0	0.0265	16.7
AQ-09	1	850628	850629	24.0	0.0180	11.3
AQ-09	1	850812	850813	26.4	0.0189	11.0
AQ-09	1	850806	850807	23.3	0.0187	12.5
AQ-09	1	850730	850731	26.5	0.0079	4.6
AQ-09	1	850724	850725	26.4	0.0445	25.5
AQ-09	1	850719	850720	25.9	0.0205	12.0
AQ-09	1	850717	850718	26.6	0.0151	8.6
AQ-09	1	850712	850713	25.0	0.0240	14.7
AQ-09	1	850705	850706	24.0	0.0147	9.4
AQ-09	1	850923	850924	25.4	0.0438	26.7
AQ-09	1	850909	850910	22.1	0.0061	4.3
AQ-09	1	850903	850904	26.4	0.0393	22.8
AQ-09	1	850828	850829	25.2	0.0228	13.9
AQ-09	1	850816	850817	23.8	0.0197	12.7
AQ-09	1	850821	850822	25.0	0.0169	10.5
AQ-09	1	850927	850928	25.3	0.0200	11.5
AQ-09	1	851001	851092	24.0	0.0051	3.1
AQ-09	1	851007	851008	26.2	0.0266	14.6
AQ-09	1	851011	851012	27.3	0.0144	7.3
AQ-09	1	851017	851018	27.4	0.0245	12.4

DATA SHEET 2- Unit 2 Station AQ-09

LACNOR SUSPENDED PARTICULATE MATTER DATA SUMMARY

STATION	UNIT	DATE ON	DATE OFF	DURATION (HR)	NET WEIGHT (G)	SPM (UG/M3)
AQ-09	2	850125	850126	24.0	0.0140	7.4
AQ-09	2	850131	850201	25.7	0.0190	9.9
AQ-09	2	850206	850207	25.5	0.0150	7.6
AQ-09	2	850212	850213	24.5	0.0150	7.8
AQ-09	2	850218	850219	24.0	0.0190	10.0
AQ-09	2	850224	850225	23.0	0.0140	7.7
AQ-09	2	850301	850302	23.0	0.0130	7.4
AQ-09	2	850307	850308	12.0	0.0320	33.9
AQ-09	2	850314	850315	23.3	0.0100	5.5
AQ-09	2	850320	850321	23.2	0.0130	7.0
AQ-09	2	850325	850326	23.0	0.0190	10.3
AQ-09	2	850401	850402	16.0	0.0070	5.6
AQ-09	2	850408	850409	23.5	0.0200	10.5
AQ-09	2	850412	850413	25.0	0.0230	11.7
AQ-09	2	850419	850420	24.0	0.0447	24.3
AQ-09	2	850425	850426	24.5	0.0191	10.4
AQ-09	2	850501	850502	24.0	0.0113	6.1
AQ-09	2	850507	850508	24.5	0.0220	11.6
AQ-09	2	850513	850514	22.5	0.0100	6.0
AQ-09	2	850517	850618	21.8	0.0055	3.4
AQ-09	2	850524	850525	24.0	0.0377	21.4
AQ-09	2	850530	850531	22.0	0.0518	32.0
AQ-09	2	850613	850614	24.5	0.0965	51.6
AQ-09	2	850619	850620	23.0	0.0294	17.1
AQ-09	2	850624	850625	24.0	0.0097	5.3
AQ-09	2	850628	850629	24.0	0.0620	35.0
AQ-09	2	850812	850813	26.4	0.0312	15.8
AQ-09	2	850806	850807	23.3	0.0273	15.9
AQ-09	2	850730	850731	26.5	0.0182	9.1
AQ-09	2	850724	850725	26.4	0.0759	38.5
AQ-09	2	850719	850720	25.9	0.0291	15.1
AQ-09	2	850617	850618	26.6	0.0274	13.7
AQ-09	2	850712	850713	25.0	0.0424	22.7
AQ-09	2	850705	850706	24.0	0.0294	16.4
AQ-09	2	850923	850924	25.4	0.0724	38.2
AQ-09	2	850909	850910	22.1	0.0118	6.9
AQ-09	2	850903	850904	26.4	0.0418	21.7
AQ-09	2	850828	850829	25.2	0.0355	18.9
AQ-09	2	850816	850817	23.8	0.0285	15.9
AQ-09	2	850821	850822	25.0	0.0318	16.8
AQ-09	2	850927	850928	25.3	0.0258	13.4
AQ-09	2	851001	851002	24.0	0.0088	4.7
AQ-09	2	851007	851008	26.2	0.0182	9.2
AQ-09	2	851011	851012	8.2	0.0162	25.4

DATA SHEET 3- Unit 3 Station AQ-10

LACNOR SUSPENDED PARTICULATE MATTER DATA SUMMARY

STATION	UNIT	DATE ON	DATE OFF	DURATION (HR)	NET WEIGHT (G)	SPM (UG/M3)
AQ-10	3	850131	850201	23.5	0.0110	8.0
AQ-10	3	850206	850207	22.0	0.0120	8.5
AQ-10	3	850212	850213	18.7	0.0130	10.0
AQ-10	3	850218	850219	20.0	0.0100	8.6
AQ-10	3	850224	850225	22.5	0.0070	5.3
AQ-10	3	850307	850307	1.6	0.0150	135.6
AQ-10	3	850314	850315	22.0	0.0050	3.3
AQ-10	3	850412	850413	23.0	0.0370	24.5
AQ-10	3	850419	850420	6.3	0.0100	23.1
AQ-10	3	850425	850426	21.5	0.0028	1.9
AQ-10	3	850501	850502	22.0	0.0016	1.2
AQ-10	3	850507	850508	25.3	0.0046	2.9
AQ-10	3	850513	850514	21.5	0.0022	1.5
AQ-10	3	850517	850518	23.8	0.0009	0.6
AQ-10	3	850524	850525	25.0	0.0191	11.3
AQ-10	3	850530	850531	25.0	0.0386	23.5
AQ-10	3	850605	850606	25.0	0.0069	4.3
AQ-10	3	850613	850613	9.8	0.0000	0.0
AQ-10	3	850624	850625	24.0	0.0068	4.2
AQ-10	3	850628	850629	23.0	0.0166	10.8
AQ-10	3	850619	850620	24.5	0.0111	6.7
AQ-10	3	850812	850813	21.4	0.0137	9.7
AQ-10	3	850806	850807	21.7	0.0165	11.4
AQ-10	3	850730	850731	22.3	0.0051	3.5
AQ-10	3	850724	850725	22.8	0.0360	23.6
AQ-10	3	850719	850720	21.1	0.0146	10.5
AQ-10	3	850712	850713	25.9	0.0217	12.5
AQ-10	3	850705	850706	21.5	0.0099	7.1
AQ-10	3	850923	850924	25.0	0.0429	26.3
AQ-10	3	850903	850904	19.8	0.0204	15.6
AQ-10	3	850828	850829	23.9	0.0181	11.6
AQ-10	3	850816	850817	24.2	0.0182	11.4
AQ-10	3	850821	850822	24.3	0.0132	8.2
AQ-10	3	850927	850928	26.4	0.0187	10.1
AQ-10	3	851001	851002	18.8	0.0040	3.0
AQ-10	3	851007	851008	26.3	0.0146	7.8
AQ-10	3	851011	851012	24.8	0.0071	4.0
AQ-10	3	851017	851018	26.4	0.0253	13.5

DATA SHEET 4- Unit 4 Station AQ-10

LACNOR SUSPENDED PARTICULATE MATTER DATA SUMMARY

STATION	UNIT	DATE ON	DATE OFF	DURATION (HR)	NET WEIGHT (G)	SPM (UG/M3)
AQ-10	4	850131	850201	23.5	0.0190	9.4
AQ-10	4	850206	850207	22.0	0.0180	9.7
AQ-10	4	850212	850213	19.2	0.0130	8.4
AQ-10	4	850218	850219	20.0	0.0180	10.9
AQ-10	4	850224	850225	22.5	0.0120	6.3
AQ-10	4	850307	850307	1.8	0.0040	28.8
AQ-10	4	850314	850315	22.0	0.0150	8.1
AQ-10	4	850412	850413	23.0	0.0590	31.1
AQ-10	4	850419	850420	6.3	0.0200	39.7
AQ-10	4	850425	850426	21.5	0.0104	5.9
AQ-10	4	850501	850502	22.0	0.0079	4.4
AQ-10	4	850507	850508	25.3	0.0165	7.7
AQ-10	4	850513	850514	21.3	0.0074	4.3
AQ-10	4	850517	850518	23.8	0.0042	2.1
AQ-10	4	850524	850525	25.0	0.0372	18.4
AQ-10	4	850530	850531	25.0	0.0547	27.1
AQ-10	4	850613	850613	9.8	0.0058	6.4
AQ-10	4	850605	850606	24.0	0.0393	19.6
AQ-10	4	850619	850620	25.0	0.0222	11.9
AQ-10	4	850624	850625	24.0	0.0233	12.7
AQ-10	4	850628	850629	23.0	0.0641	37.4
AQ-10	4	850812	850813	21.4	0.0207	13.0
AQ-10	4	850806	850807	21.7	0.0232	14.5
AQ-10	4	850730	850731	22.3	0.0110	6.6
AQ-10	4	850724	850725	22.8	0.0507	30.2
AQ-10	4	850719	850720	21.1	0.0210	13.3
AQ-10	4	850712	850713	25.9	0.0310	15.9
AQ-10	4	850705	850706	21.5	0.0204	12.9
AQ-10	4	850923	850924	25.0	0.0909	48.8
AQ-10	4	850903	850904	19.8	0.0475	32.6
AQ-10	4	850828	850829	23.9	0.0221	12.4
AQ-10	4	850816	850817	24.2	0.0236	13.0
AQ-10	4	850821	850822	24.3	0.0275	15.2
AQ-10	4	850927	850928	26.4	0.0189	8.1
AQ-10	4	851001	851002	18.8	0.0060	4.0
AQ-10	4	851007	851008	26.3	0.0227	10.8
AQ-10	4	851011	851012	24.8	0.0104	5.2
AQ-10	4	851017	851018	26.4	0.0295	14.1

Number/
Numéro

3

CONTRACT SERIAL NUMBER: OSQ84-00196
CONTRACTOR: GOLDER ASSOCIATES
REQUISITION NUMBER 23241-4-1680

LACNOR FIELD STUDY
ELLIOT LAKE, ONTARIO

APPENDIX 3
SURFACE WATER STUDIES

Prepared for

The National Uranium Tailings Program

By

Golder Associates
Beak Consultants SENES Consultants
Cumming - Cockburn & Associates

March 1986

88 pp - 2 fig pp.

APPENDIX 3 SURFACE WATER STUDIES

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APPENDIX 3 - SURFACE WATER STUDIES

3.1 Introduction

3.1.1 Scope and Objectives

In December, 1984, Golder Associates, SENES Consultants Limited, BEAK Consultants and Cumming-Cockburn & Associates Limited were awarded a contract by the National Uranium Tailings Program to carry out the field study at the Lacnor Uranium tailings area in Elliot Lake, Ontario. The intent of the project, as set out in the terms of reference was:

> "The design and operation of a sampling program, incorporating chemical, physical and biological data that will be used to characterize the Lacnor tailings and environs, and which will provide raw data for the study of processes involving tailings constituents and their pathways."

The field study therefore, required the sampling of tailings solids, subtailings soil and rock, the surrounding soil and rock, tailings porewater, surface water, the measurement of surface water runoff, the gathering of atmospheric data and a biological assessment of the site.

This appendix (Appendix 3 to the main overview report) includes details regarding the hydrology and surface water quality of the Lacnor uranium tailings area. Details of the field work carried out during the period December 1984 to November 1985 and all the results obtained are presented in this factual report. Overall interpretation of these results has been excluded from this study.

3.1.2 Appendix Outline

This appendix is organized into the following sections:

3.2 Hydrologic Studies, presents the results of the surface water discharge monitoring program carried out during the study period. The three surface water discharge monitoring installations, equipment and calibration, and flow measurements are described in this section.

3.3 Chemical Studies, presents the chemical analysis results of the surface water streams sampled at the three locations of the water level recorders. Sampling procedures, laboratory procedures, analytical results, radiocationic data and interlaboratory comparisons are described in this section.

3.1.3 Schedule of Events

A field reconnaissance survey was undertaken in July 1984 to identify potential monitoring locations. Detailed site evaluations were carried out in November 1984 with subsequent installation of the monitoring weirs in January 1985. Surface water samples were collected on a weekly to biweekly basis from late January to the end the October 1985.

3.2 Hydrologic Studies

3.2.1 General

Characterization of the surface runoff from the Lacnor tailings management area was recognized to be an important component of the field study requiring collection of continuous discharge data. Past experience has shown that the absence of such data has been a major deficiency in undertaking hydrologic investigations for small watersheds in the Elliot Lake area. In fact, very few flow measurements are taken regularly for small watersheds in Ontario.

A micro-drainage plan of surface water pathways was also developed using the 1985 1:2000 scale topographic map (see Figure 3.1) in conjunction with field surveys to determine the following flow path characteristics:

- limits of the tailings surface area,
- surface drainage pathways in the tailings surface,

- watershed areas adjacent to the tailings area,
- direction and contributing areas of main flow paths,
- marsh/swamp areas and other hydrologic features,
- natural and man-made features affecting the flow path such as channels, dams, dykes, or swales, and
- ponded areas and storage characteristics.

The above information is depicted on Figure 3.1. The bathymetry of the ponded area is depicted on Figure 3.2.

The surface water measurement program was designed to provide accurate data for future input to a suitable hydrologic model for the purpose of assessing the net amount and quality of water exiting the basin as surface runoff. A field reconnaissance survey was undertaken on 18 July 1984 to identify potential monitoring locations. The locations subsequently were confirmed by topographic surveys and detailed site evaluations conducted during the week of 21 November 1984. Three monitoring locations were established:

i) Station SW-01 is situated south (downstream) of the Lacnor tailings containment dyke just west of the main dam on West Creek (primarily seepage flow)
ii) Station SW-02 is located south (downstream) of the Lacnor tailings main dam on East Creek (primarily seepage flow)
iii) Station SW-03 is approximately 175 m downstream from the outlet of the Lacnor tailings pond at the east end of the tailings area at the Rio Algom station L-3 (primarily surface flow).

The locations of the discharge monitoring stations are also shown on Figure 3.1.

Experience with other applications on watersheds of similar size in northern Ontario indicated that relatively low flows should be measured by recording water levels over a V-notch (field calibrated) weir. The equipment housing should be heated and the weirs insulated in the winter to avoid loss of data

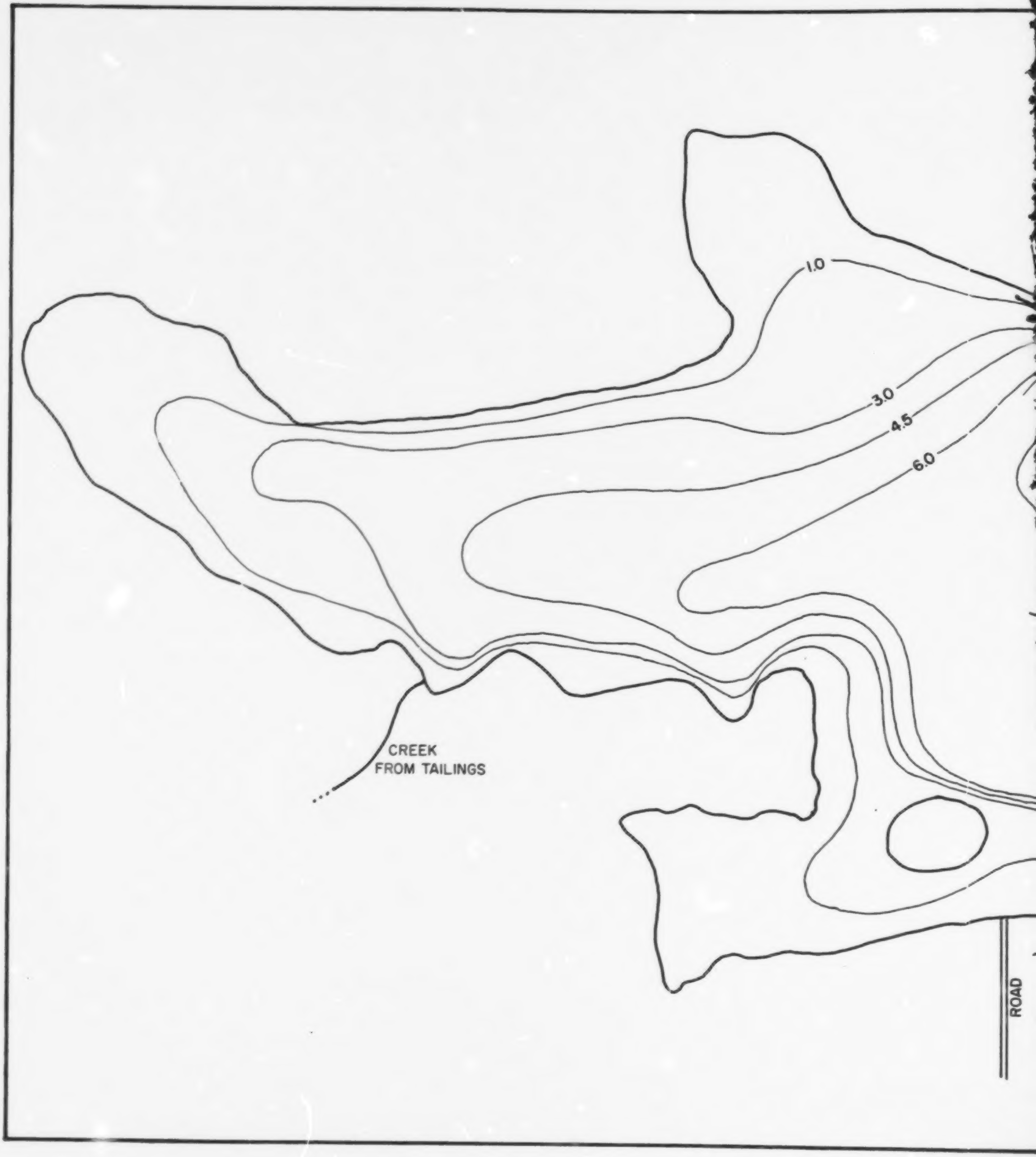
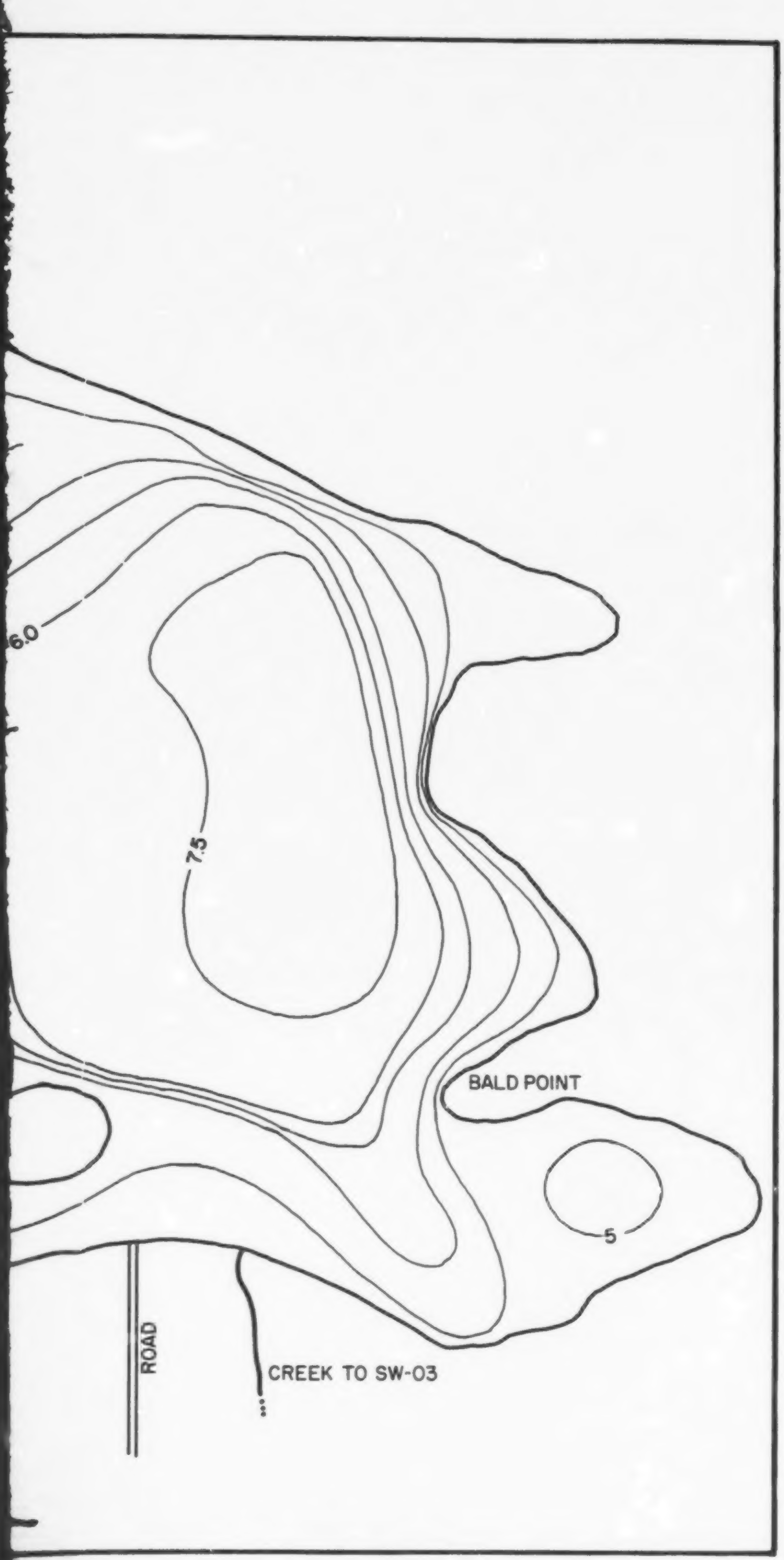

1.0
3.0
4.5
6.0
CREEK
FROM TAILINGS
ROAD

FIGURE 3.2

SURFACE WATER
BATHYMETRIC SURVEY
OF PONDED AREA


6.0
7.5
BALD POINT
5
ROAD
CREEK TO SW-03

DEPTHS IN METERS

0
0.5
1.0 Km
N

during spring snowmelt or winter thaw periods. A description of the monitoring set-up is provided in Section 3.2.2.

It has been observed that the Lacnor discharge is reduced significantly by the time it reaches the downstream Nordic tailings area due to exfiltration and other losses. It was, therefore, of optimum importance to locate the discharge measuring locations as close as possible to the point of discharge from the Lacnor tailings area. While this gave rise to a number of logistical problems, such installations were considered necessary to provide an accurate time-varying discharge record at each location.

The discharge monitoring locations installed on West and East Creeks (SW-01 and SW-02, respectively) were located to monitor seepage from the tailings area. Due to physical and geomorphological constraints in constructing the weirs at the base of the dam, the weir locations had to be installed slightly downstream. Therefore, some runoff from the local contributing lands is reflected in the discharge records for Stations SW-01 and SW-02. The recorded discharge values should be adjusted to account for the additional drainage area before conducting any subsequent data analyses in regard to seepage losses from the Lacnor tailings area.

To be consistent with previous spot discharge measurements taken by Rio Algom between 1980 and 1984 of the outflow from the pond at Lacnor, monitoring station SW-03 was located on Lacnor Creek at Rio Algom Station L-3.

The monitoring installation procedures undertaken, and results obtained at each of the gauging sites are further discussed in the following sections.

3.2.2 Discharge Monitoring Equipment

At three monitoring locations, concrete weirs were constructed with a steel V-notch centre plate. Concrete stilling wells (approximately 1.0 m^2 inner area) were constructed and a wood frame housing was mounted over each to protect the recording apparatus. The huts were heated to 18°C during the winter months using a propane type catalytic heater (Ciscan Type E orifice heater) to prevent freezing of the stilling wells. The upstream stilling pool at each weir was also covered with a removable, insulated housing to prevent freezing at the weir V-notch. Photographs of the various monitoring locations during construction and operation are included at the end of this appendix. A more detailed description of the weir construction and installation, is provided in the design construction drawings developed as part of this study. These drawings are included in the project box file material.

Continuous water level records were collected using Leupold-Stevens Model A-71 float-operated, water level recorders. The operating principle of these recorders is simple. A graduated tape with a counterweight on one end and float on the other is hung over a pulley. This float, resting on the surface of the water in the stilling well moves the graduated tape up or down as the water level in the stilling well fluctuates, thus rotating the pulley. The rotation of the pulley, which is directly related to the variation in water level, is registered on a graduated chart located in the recorder. The recorder is equipped with a spring-driven clock mechanism which advances the chart paper at a constant speed. Thus, a constant analog record is obtained of changes in water level over a given time period.

All three recorders were calibrated according to the recommended techniques of Leupold & Stevens (1978) for small watersheds. The following parameter definitions were set for each recorder installation:

- A 4.5 month unattended Chelsea clock was used as the chart drive mechanism.
- Time scale (horizontal chart movement) was calibrated to 6.1 cm per day
- Gauge scale (variation in water level vs. chart representation) was calibrated to a ratio of 1:1 (i.e. 1 cm rise in water level is charted as a 1 cm rise on the chart record).
- A 375 mm circumference float pulley was used.
- A 300 mm diameter float (with counterweight) was used.

Flow monitoring was initiated in mid-February 1985. However, problems encountered with the water freezing in the stilling wells prevented accurate measurements for the operating period prior to mid-March 1985. The problem was rectified with the use of additional Ciscan heaters mounted beneath the floor of each stilling well hut. Continuous discharge monitoring was achieved over the duration of the study period, 23 March 1985 through 3 November 1985.

Over the course of the monitoring program, spot discharge and water level measurements were made at each gauging site to aid in verifying the accuracy of the discharge records. These data consisted of random estimates of discharge at the weir section and of water level in the stilling wells. These measurements were used in conjunction with theoretical techniques and other data to define the rating curves derived for each gauging station presented in Table 3.1.

3.2.3 Weir Calibration

The measurement of flow in an open channel from small watersheds can never be other than an approximation of actual physical circumstances as no absolute values can be obtained in the field. For the majority of flow measuring installations, errors within a range of 15 to 20% are common (L. Scott, 1984).

Errors in calibration of theoretical to actual estimates can encompass any one of, or combination of, the following factors:

- The approach velocity of flow.
- The depth of flow at nappe versus angle of cut on the weir plate.
- The amount of fall or head loss in the channel at minimum flow.
- The minimum head that exists under average flow conditions over the weir. (For small discharge amounts, the nappe may cling to the weir crest, thus reducing the efficiency of the section and lowering the weir coefficient.)

Table 3.1 : **SURFACE WATER - SUMMARY OF RATING CURVE EQUATIONS**

Station	Rating Curve Equation	
SW-01	$Q = 1.65\ H^{2.5}$	when $H \leq 0.525$ ft
	$Q = 4.82\ H_a^{1.5} + 3.7\ H^{2.5}$	when $0.525 \text{ ft} < H < 1.417$ ft
SW-02	$Q = 2.74\ H^{2.5}$	when $H \leq 0.517$ ft
	$Q = 5.29\ H_a^{1.5} + 2.74\ H^{2.5}$	when $0.517 \text{ ft} < H \leq 1.0$ ft
SW-03	$Q = 3.7\ H^{2.5}$	when $H \leq 0.68$ ft.
	$Q = 4.81\ H_a^{1.5} + 3.7\ H^{2.5}$	when $0.68 \text{ ft} < H \leq 1.0$ ft.
	$Q = 7.41\ H_a^{1.5} + 4.81\ H_a^{1.5} + 3.7\ H^{2.5}$	when $H > 1.0$ ft

Notes

Q = Discharge in cfs*
H = Head (ft)
$H_a = H - 0.525$ for SW-01
$H_a = H - 0.517$ for SW-02
$H_a = H - 0.68$ for SW-03

* Equations derived in Imperial units. Divide discharge values by 0.03534 to convert to L/s

- Accuracy in measuring the water level and flow at small heads over the weir section.

Installation and site constraints such as geomorphologic conditions can also affect the accuracy of flow measurements. For example, the foundation material at site SW-02 was primarily tailings material and prone to erosion. Also, the weirs were constructed during the winter on frozen ground conditions.

During the spring melt, some undercutting of the weir occurred at the SW-02 location. The weir became inoperative for the period April 1 to April 6, 1985. The weir subsequently was repaired by excavation of the foundation material on the upstream side and placement of an impermeable barrier overlain with clay backfill and tailings material to eliminate seepage under the weir. This problem was not encountered at the other two sites where the weirs were constructed on bedrock.

As a result of the site examinations and a review of historical discharge data for the Lacnor area, staged 90 V-notch/rectangular weirs were installed. This type was selected due to the highly variable discharge expected from the tailings area and the adjacent watersheds.

The general forms of the flow equations for this type of weir are (King, 1976):

for 90° V-notch, $Q = CH^{2.5}$

for rectangular section $Q = CLH^{1.5}$

where Q = discharge in ft/s

C = weir discharge coefficient

H = head (ft)

L = weir crest length (ft)

Calibration of the weirs to field (bucket type) spot flow measurements was undertaken to determine the weir coefficients under actual events. This was found to be especially important in considering the relatively small discharge rates (i.e. flow depths of less than 6 cm at the nappe) measured over the summer months.

Spot discharge and water level measurements were taken at each weir location on 14 different occasions during the course of the study to provide data for calibration of the weir coefficients. The number of measurements and timing of each were undertaken primarily to provide a range of records for calibration of the weirs at various heads. The procedures used and timing of these measures were in keeping with guidelines suggested by Water Survey of Canada (McCurry, 1984).

Site visits were made weekly as a secondary check for chart slippage and to ensure the weirs were kept free of debris and remained operational. During each site visit, the relationship of chart record to depth at nappe was recorded along with any observations of conditions that might affect the accuracy of measurements over the preceding time frame. This ensured that accurate representations of the hydrologic characteristics of the basin runoff were collected during the monitoring investigations and that the measurement error was within acceptable limits (15 to 20%). The resulting weir rating equations are given in Table 3.1. The computations using these equations were carried out in Imperial units as the equations were originally formed in this system (King,1976). The results were then converted to metric units and are summarized in Tables 3.2 to 3.4.

It should be noted that only the portion of the rating curves applicable to the V-notch sections were calibrated to known discharges at weirs SW-01 and SW-02. This was due to the absence of collected calibration data for the rectangular section of the control weirs. During the survey period flows were not observed to exceed the V-notch sections at sites SW-01 or SW-02. While two such occurrences were observed at site SW-03. Caution should be used when applying the SW-01 and SW-02 results of any flows outside the calibrated range.

Table 3.2 : **SURFACE WATER - DAILY FLOW, STATION SW-01**

Day	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	-	0.79B	0.91	0.39	0.15	0.18	0.15	0.23	0.30
2	-	0.88	0.71	0.30	0.14	0.24	0.16	0.18	0.42
3	-	0.87	0.54	0.28	0.14	0.25	0.39	0.16	0.64
4	-	0.76	0.60	0.30	0.16	0.26	0.20	0.39	0.98
5	-	0.80	0.76	0.30	0.14	0.27	0.17	0.34	-
6	-	2.36	0.65	0.30	0.14	0.51	0.17	0.21	-
7	-	1.41	0.69	0.29	0.14	0.24	0.16	0.19	-
8	-	1.12	0.83	0.28	0.13	0.18	0.16	0.34	-
9	-	0.90	0.63	0.29	0.13	0.15	0.23	0.25	-
10	-	0.80	0.50	0.31	0.16	0.13	0.25	0.25	-
11	-	0.78	0.43	0.27	0.17	0.12	0.22	0.25	-
12	-	0.85	0.42	0.41	0.18	0.12	0.20	0.34	-
13	-	0.81	0.40	0.41	0.50	0.14	0.20	0.32	-
14	-	0.92	0.37	0.42	0.16	0.13	0.22	0.22	-
15	-	2.13	0.36	0.42	0.18	0.11	0.23	0.40	-
16	-	2.53	0.43	0.45	0.18	0.11	0.24	0.31	-
17	-	1.81	0.39	0.48	0.18	0.11	0.30	0.29	-
18	-	-	0.33	0.55	0.16	0.61	0.38	0.37	-
19	-	-	0.30	0.57	0.12	0.17	0.41	0.36	-
20	-	-	0.29	0.38	0.13	0.16	0.46	0.34	-
21	-	-	0.30	0.22	0.18	0.16	0.27	0.33	-
22	-	-	0.25	0.33	0.18	0.16	0.31	0.32	-
23	-	2.66	0.25	0.25	0.24	0.17	0.40	0.32	-
24	-	1.99	0.25	0.21	0.30	0.17	0.34	0.31	-
25	-	1.53	0.28	0.21	0.54	0.16	0.23	0.30	-
26	-	1.27	0.30	0.20	0.18	0.19	0.20	0.31	-
27	-	0.86	0.28	0.17	0.12	0.18	0.13	0.33	-
28	-	0.78	0.27	0.16	0.13	0.17	0.14	0.27	-
29	-	0.70	0.26	0.15	0.14	0.20	0.13	0.19	-
30	0.97B	0.79	0.30	0.15	0.16	0.16	0.23	0.17	-
31	0.87B		0.64		0.17	0.15		0.23	-
Mean	-	-	0.45	0.32	0.18	0.20	0.24	0.28	-

Notes

All flow rates measured using a continuous recording regulated gauge and displayed in L/s.
B = ice conditions
Maximum Daily = 2.66 L/s on 23 April 1985.

Table 3.3 : **SURFACE WATER - DAILY FLOW, STATION SW-02**

Day	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
1	2.07B	2.16E	17.5	10.7	1.45	1.02	1.11	1.19	1.38
2	2.03B	1.76E	16.7	10.1	1.50	0.99	1.07	1.06	2.31
3	2.05B	1.73E	15.9	9.42	1.38	0.98	2.22	0.99	4.85
4	2.04B	1.97E	15.6	8.58	1.38	0.94	1.20	2.40	5.85
5	1.98B	2.29E	16.7	8.64	1.36	2.06	1.17	2.32	-
6	1.71B	5.97	16.5	8.52	1.26	2.44	1.20	2.40	-
7	1.56B	3.11	16.7	8.12	1.37	1.35	1.17	2.82	-
8	1.55B	2.69	16.9	7.67	1.18	1.16	1.14	4.22	-
9	1.55B	2.48	16.3	7.16	1.20	1.12	1.40	3.16	-
10	1.55B	2.47	16.2	6.49	1.25	1.29	1.20	1.47	-
11	2.35B	2.32	15.6	5.96	1.22	1.18	1.11	1.87	-
12	3.06B	2.58	15.3	5.64	1.17	1.18	1.06	1.83	-
13	1.81B	2.57	11.9	5.29	1.13	1.86	1.01	1.56	-
14	1.77B	2.82	11.9	4.74	1.15	1.19	0.99	1.32	-
15	1.78B	5.05	11.2	4.05	4.08	1.03	0.99	1.18	-
16	1.76B	6.35	11.7	3.47	1.33	1.01	0.97	1.20	-
17	1.91B	5.16	11.2	3.91	1.29	0.97	0.96	1.21	-
18	1.98B	7.50	11.2	3.90	1.30	3.07	0.97	1.22	-
19	-	9.25	10.3	2.78	1.11	1.25	0.94	1.23	-
20	-	11.72	10.3	2.25	1.03	1.12	0.98	1.28	-
21	-	12.86	9.40	1.92	1.45	1.16	1.04	1.33	-
22	-	13.05	8.75	2.79	1.09	1.15	1.16	1.35	-
23	-	9.97	8.50	1.92	1.07	1.19	1.65	1.34	-
24	-	7.03	9.21	1.78	1.06	1.38	1.55	1.33	-
25	-	15.19	9.16	1.65	3.03	1.15	1.57	1.60	-
26	-	17.64	9.00	1.63	1.41	1.40	1.63	1.45	-
27	-	18.11	8.42	1.59	1.23	1.25	1.13	1.39	-
28	-	18.09	7.69	1.53	1.37	1.10	1.03	1.41	-
29	-	18.07	7.05	1.49	1.18	1.50	1.05	1.40	-
30	1.68	18.06	7.34	1.45	1.11	1.16	1.39	1.36	-
31	1.87		10.4		1.11	0.99		1.32	-
Mean	-	7.49	12.3	4.84	1.40	1.31	1.20	1.65	-

Notes

All flow rates measured using a continuous recording regulated gauge and displayed in L/s.
E = estimated flow
B = ice conditions
Maximum Daily = 18.11 L/s on 27 April 1985

Table 3.4 : **SURFACE WATER - DAILY FLOW, STATION SW-03**

Day	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
1	-	45.0	5.83R	2.91R	0.29	0.39	0.64	0.42	2.56
2	-	43.8	5.75R	2.54R	0.29	0.38	0.67	0.61	2.77
3	-	42.5	5.57R	1.89R	0.29	0.38	1.23	0.69	29.0
4	-	40.5	5.07R	1.70R	0.30	0.37	2.50	0.85	-
5	-	40.1	6.14R	1.50R	0.34	0.36	1.61	2.36	-
6	-	49.4	6.75R	1.54R	0.34	0.35	1.13	1.07	-
7	-	51.9	6.44R	1.55R	0.33	0.36	0.75	0.66	-
8	-	47.8	5.88R	1.56R	0.33	-	0.63	1.22	-
9	-	45.4	5.28R	1.28R	0.32	2.88	0.38	2.69	-
10	-	43.6	4.73R	0.83R	0.32	1.90	0.35	16.2	-
11	-	41.4	4.63R	0.65R	0.48	1.55	0.32	16.0	-
12	-	40.3	4.53R	0.64R	0.61	1.08	0.25	14.0	-
13	-	40.2	4.44R	0.64R	0.61	1.74	0.20	16.1	-
14	-	40.2	4.34R	0.64R	0.61	1.62	0.18	21.7	-
15	-	43.8	4.25R	0.64R	0.61	1.27	0.17	17.9	-
16	-	62.4	4.16R	0.63R	0.61	0.82	0.16	14.4	-
17	-	87.5	4.07R	1026. E	0.61	0.56	0.19	11.9	-
18	-	127.	3.98R	522. E	0.61	6.37	0.19	10.0	-
19	-	535.	3.90R	279. E	0.60	3.71	0.19	8.55	-
20	-	528.	3.21R	26.4 E	0.59	1.74	0.19	12.9	-
21	-	539.	2.50R	16.8	0.58	1.33	0.20	14.0	-
22	-	532.	2.50R	18.0	0.57	1.05	0.22	11.5	-
23	-	532. E	2.40R	2.16	0.56	0.83	0.28	10.1	-
24	-	12.2R	2.29R	1.02	0.55	0.79	0.93	8.12	-
25	-	11.5R	1.99R	0.52	0.32	0.62	0.41	6.71	-
26	43.0B	10.3R	1.78R	0.30	0.16	0.61	0.43	6.34	-
27	42.9B	10.3R	1.79R	0.46	0.16	0.54	0.47	5.56	-
28	42.8B	8.96R	1.80R	0.46	0.16	0.47	0.47	4.65	-
29	43.7B	7.56R	1.69R	0.41	0.16	0.42	0.45	3.99	-
30	45.4	7.13R	1.51R	0.28	0.26	0.40	0.38	3.40	-
31	46.5		2.23R		0.34	0.51		3.02	-
Mean	-	123.6	3.92	63.8	0.42	1.18	0.54	7.99	-

Notes

All flow rates measured using a continuous recording regulated gauge and displayed in L/s.
E = estimated flow
B = ice conditions
R = regulated
Maximum Daily = 1026E L/s on 17 June 1985

3.2.4 Missing Data and Man-made Constraints

As a result of flooding downstream at the Nordic tailings area, Rio Algom constructed an earthen dam at the outlet of the Lacnor Ponds just upstream of station SW-03. The dam was intended to attenuate flows from the Lacnor tailings area and reduce the flooding being experienced downstream in the Nordic basin. The discharge records at locations SW-02 and SW-03 were affected by the temporary upstream dam from 24 April to 17 June 1985.

As a result of this dam the water level of Lacnor Pond was increased by more than 60 cm. This caused water to back up and overflow onto the Lacnor tailings. The flooding of the Lacnor tailings area resulted in water running along a natural swale and through an overflow spill gate in the main tailings dam. This gate drained to East Creek and contributed to the flow being recorded at station SW-02. The net effect of the earthen dam was to reduce recorded flows at SW-03 and increase the flows being recorded at SW-02. Photographs of the extent of the flooding are included at the end of this appendix.

The earthen dam on Lacnor Creek was removed on 17 June 1985 by Rio Algom. This caused relatively high flows at station SW-03 for the following two-day period as the stored water was released. During the period from 17 June to 20 June 1985, the water level in Lacnor Pond dropped more than 60 cm. Associated with this decrease, high velocities and accumulations of debris were experienced at station SW-03. Due to the amount of debris accumulation at SW-03 for the two-day period following the temporary dam removal, the discharge flows should be treated as estimates only.

The discharge records presented on Tables 3.3 and 3.4 for the period 24 April to 20 June 1985 should be interpreted with caution as a result of the man-made alterations to the natural drainage characteristics of the area.

Some other periods of missing data were also experienced during the course of the monitoring study, as apparent in the review of Tables 3.2 to 3.4. These were primarily attributed to the effects of ice or debris accumulations at the V-notch.

Some data losses were encountered during the initial monitoring period due to the freezing in the gauging station huts discussed earlier. This was rectified in mid-March with the installation of propane heaters. Upon installation of these units, no further loss of data due to freezing problems in the stilling wells was experienced.

The water level/discharge monitoring program was discontinued on 4 November 1985 (the completion of the monitoring phase of the study). At this time, the recorders were removed from sites SW-01 and SW-02. The monitoring equipment was left operational at gauge site SW-03 as monitoring will be continued by Rio Algom.

3.2.5 Surface Water Discharge Measurements

The spring runoff of 1985 in the Elliot Lake region has been documented as being one of the most severe on record (Nickel District Conservation Authority, 1985). However, due to the man-made effects of the temporary dam on the Lacnor basin outflows, only limited quantitative estimates were collected during this monitoring program.

The daily flow summaries were derived based on the reduction of the strip data in hourly intervals, converted to hourly discharge values and averaged over the 24-hour period. The rating curves used in the data reduction are given in Table 3.1 and are based on the general form of the equations presented in Section 3.2.3.

In general terms, Tables 3.2 to 3.4 illustrate the variety in magnitude of seasonal variations in discharge experienced in the watershed. Table 3.4 illustrates the uniformity in magnitude of discharge recorded during the summer months. Due to the proximity of the gauge to Lacnor Pond, it is postulated that the effect of the pond on attenuating runoff from rainfall events is significant.

The measurements made at monitoring locations SW-01 and SW-02 (see Tables 3.2 and 3.3) indicate that seepage rates are relatively constant on a seasonal basis. In examining the discharge records, care should be taken in the assessment of variation in flow magnitude due to the effects of precipitation.

A cursory examination of the hourly discharge and water level records for the Lacnor basin shows the "flash-flood like" nature of basin runoff with respect to a given event. In examining the response of the watershed to rainfall or snowmelt events, hourly discharge records should be used. These records are available for the three gauging sites although their inclusion in this report was not required. This information is included in the project box file with the supplemental material submitted in conjunction with this report.

3.3 Surface Water Chemical Studies

This section presents the methods used for collecting surface water samples at the Lacnor site, shipping and subsequent chemical analyses.

3.3.1 Field Sampling Methods

Samples were collected from three surface water streams at the same location as the water level recorders (SW-01, SW-02, SW-03) on approximately a weekly to biweekly basis. The water samples for chemical analysis from the three streams (SW-01, SW-02, SW-03) were collected, either from the pool formed by the weir plate or from the constricted flow passing over the weir, in a 6-litre stoppered plastic bottle filled to the top. The same bottle was used at a particular surface water station. It was washed in the field laboratory with weak nitric acid and then distilled water. It was washed twice with sample from the stream before final filling. Water temperature was measured at the time of sampling using a mercury glass thermometer.

The samples were returned to the field laboratory for analysis, sample splitting and shipment, after completion of maintenance operations on the water level recorders. The elapsed time between taking samples at the first weir and returning them to the field laboratory was typically two hours.

3.3.2 Field Laboratory Measurements

Redox potential was measured in the field laboratory with an Orion Combination Redox Electrode (96-78-00) connected to an Ionalyzer Orion Research Specific Ion Meter Model 407. A Zobell solution (Zobell, 1946; Nordstrom, 1977) was used to check the meter. The potential of the Zobell solution can be calculated from the relationship:

$$E \text{ (Volts)} = 0.43028 - 2.5157\text{x}10^{-3} (t-25) - 3.7979\text{x}10^{-6} (t-25)^2$$

developed by Nordstrom (1977). Accordingly, the reference solution was calculated to have an Eh of 378 mV at 4°C and 413 mV at 18°C.

The pH of the sample was measured in the field laboratory with a portable Digital pH meter calibrated with pH 4 and pH 7 buffers. Because the pH of the three surface streams was generally in the range of 3 to 4, the pH 4 buffer was the primary standard used for instrument calibration.

Acidity was measured by titration of the sample from the environmental pH to pH 8.3 with sodium hydroxide using a pH meter to detect the endpoint. The term "acidity" operationally defines the proton condition of the system with respect to a reference proton condition (equivalence point). Selection of a pH 8.3 endpoint assumes the bicarbonate equivalence point of $(H_2CO_3{}^*) = (CO_3^{2-})$ for a water solution containing approximately 10^{-3} to 10^{-4} molar total inorganic carbon (C_T) the carbon concentration measured in the three surface water streams. At the pH 8.3 endpoint, the reference proton condition is called the CO_2-acidity condition, and is equivalent to:

$$(H_2CO_3{}^*) + (H^+) - (CO_3^{2-}) - (OH^-)$$

Here: $(H_2CO_3{}^*)$ is the carbonic acid concentration,
(H^+) is the hydrogen ion (proton) concentration,
$(CO_3^{2}$-0) is the carbonate concentration, and
$(HCO_3{}^-)$ is the bicarbonate concentration.

An alternative proton condition considered was the mineral-acidity (H-Acy) condition defined as:

$$(H\text{-}Acy) = (H^*) - (HCO_3{}^-) - 2(CO_3^{2-}) - (OH^-)$$

The difference between these two proton conditions can be described with the following example. Consider a water sample devoid of cations which hydrolyze. The endpoint for mineral acidity would be approximately pH = 4.5 for $C_T = 10^{-3}$ to 10^{-4} M, while the endpoint for CO_2_acidity is approximately pH of 8.3.

Titration of this water sample from a pH of approximately 3 to 4.5 with base (NaOH) represents neutralization of most free H^+, while the titration from pH 4.5 to 8.3 represents conversion of $H_2CO_3^*$ to HCO_3^-.

However, in the Lacnor surface water samples, the titration is complicated by the presence of cations which hydrolyze, mainly Fe^{2+} and Fe^{3+}. The theoretical mineral acidity endpoint, defined as $(H^+) = (HCO_3^-)$, will vary from pH = 4.3 to 4.8 for C_T ranging from 10^{-3} to 10^{-4} M. Secondly, the detection of the end point by interpretation of a titration curve is difficult because the inflection point is broadened by hydrolysis and polymerization reactions of Fe^{2+} and Fe^{3+} over pH 3 to 5. Accordingly, it was decided to measure the CO_2-acidity endpoint for the Lacnor field program. Thus, these acidity measurements include the effect of hydrolysis of Fe^{2+} and Fe^{3+}, neutralization of H^+, and conversion of $H_2CO_3^*$ to HCO_3^-.

Fe^{2+} was measured using the titration procedure of Waser (1966) in which a redox colour indicator defines the end of the titration. A phosphate quencher is added to a suitable aliquot of sample, complexing and stabilizing the Fe^{2+} ion. This solution is titrated with potassium dichromate.

Specific conductance was measured using a Sproule Electrolytic Conductivity Cell (K = 0.1) connected to an Electronic Switchgear Conductivity Meter. Its calibration was checked with KCl standard solution and found to be constant over the course of the project. Values reported in Table 3.5 are those measured at the sample temperature in the field laboratory. Samples were not allowed to warm to a reference temperature (e.g. 20°C) because the oxidation of Fe^{2+} would change the conductance of the solution by changing the net charge and the hydrolytic state of iron. A temperature adjustment to 20°C is not computed because each ion has a different temperature coefficient. For example, electrolytic conductivity increases with temperature at a rate of 2%/degree C for typical surface waters, whereas the temperature correction is substantially less than that for KCl solutions (APHA, 1983). A temperature adjustment could be estimated by consideration of temperature adjustments for the mean constituents of the waters (Fe^{2+}, Fe^{3+} and their hydrolyzed species, aluminum, calcium, hydrogen and sulphate) and a few experimental measurements.

Dissolved oxygen measurements were initiated midway through the field program. A dissolved oxygen membrane probe and probe-mixer, connected to a YSI Model 54 dissolved oxygen meter, were used on samples in the field laboratory. The probe was stored in distilled water between field sampling intervals. The meter was standardized before use with a distilled water solution saturated by bubbling air through it with a diffuser stone for one hour. The saturation concentration was established from tables for the temperature of the solution.

3.3.3 Sample Subdivision, Preservation and Shipment

Samples were taken from the 6-L bottle for measurement of dissolved oxygen, redox potential, conductivity, Fe^{2+} and acidity. Sample bottles for shipment of samples to the chemical laboratories had previously been washed with nitric acid. These bottles were rinsed twice with sample water before filling. The following size of bottles and preservation techniques were generally used:

Quantity	Size	Analysis	Preservative
1	100-mL plastic bottle	Metals	HNO_3
2	1-L plastic bottles	Radionuclides	HNO_3
1	250-mL bottle	Nutrients	H_2SO_4
1	250-mL bottle	Anions	None (keep cool)

Samples for TOC and TIC were initially taken from the full, unpreserved bottle for anions. Due to the possibility of degassing, a different technique was subsequently implemented. It consisted of filling a glass culture tube (3 cm x 15 cm) with sample, and stoppering with an air-tight cap with inverted cone to displace any air at the top of the sample bottle.

For a few samples, additional bottles were filled with sample filtered through a 0.45 um micropore filter. An aliquot of these samples was left unpreserved and analyzed for anions. Another aliquot was preserved and analyzed for metals to determine whether there was a substantial particulate component in the samples. However, the filter papers had a substantial reddish-orange colour after filtration. This colour results from trapping colloidal iron hydroxide on the filter paper (under a nitrogen atmosphere) or colloidal plus Fe^{2+} which is oxidized and precipitated on the filter paper (under an air atmosphere). A few filter papers were analyzed for metals early in the sampling program (March 1985). It was subsequently decided not to filter samples because of the possible removal of metals and radionuclides with the colloidal iron.

During two sampling periods, a few samples were filtered. For a three-day period in late April after the initiation of snowmelt, samples from SW-02 were filtered because water ponded on the surface of Lacnor tailings was flowing through an old, broken, wooden drain located 3 m below the top of the tailings dam and approximately 10 to 15 m above the visible height where water was seeping through the dam. These samples appeared milky-brown in colour, and contained tailings solids eroded by the water flowing from the surface of the tailings. Because these samples were assumed to be a non-normal spring runoff event, only dissolved constituents were measured.

Secondly, for a few days after an earth barrier was placed by Rio Algom across the channel at SW-03, seepage samples through the dam were filtered prior to shipment for metal and radionuclide analyses. However, for the remaining period that the dam was in place, samples were taken upstream of the dam and hence not filtered.

The sample preservation procedures are those suggested by the U.S. EPA (1974) and Chiu and Dean (1984). The preservation procedures for normal (pH 7 to 8) surface waters are as follows. For acidity, it is recommended that samples be kept cool (4°C) for a maximum holding time of one day. For dissolved oxygen, it is recommended that D.O. be determined on site immediately. For pH, on-site determination is recommended with a holding time of up to six hours. For nutrient parameters, it is recommended that they be preserved with sulphuric acid to a pH of less than 2, kept cool and analyzed within seven days.

For sulphate, it is recommended that the sample be kept cool at 4°C with a holding time of one week. For specific conductance, a storage temperature of 4°C and a 24-hour holding time are recommended. For metals, a HNO_3 reservative with a holding time of up to six months is recommended; the preservative should lower the pH to less than 2. These procedures were generally used in this study, with the exception of holding times for a few parameters.

3.3.4 Typical Sampling Day

The following is the typical daily routine used by the local field technician. The technician left the field office for Lacnor site between 8:00 and 8:15 a.m. after phoning Rio Algom security to alert them to the fact that a man was going on-site. This was a safety precaution in case a field accident made them unable to return. Sampling started at approximately 8:30 a.m. at SW-03, followed by SW-02 and SW-01. Sampling and gauge maintenance at the three stations was generally finished by 10:00 to 10:30 a.m. After return to the field laboratory, an aliquot of the sample was analyzed for dissolved oxygen, Eh and conductivity. The remaining sample was split into sample bottles for shipping to laboratories for radionuclides, cations, and anions, analysis, preservative was added, and the samples were cooled if required. This was completed by noon.

After noon, Fe^{2+} and acidity were measured. This was generally completed by 2:00 p.m. after which the samples and shipping sheets were prepared for ground shipment by courier for overnight delivery. The sample shipping sheets gave the field laboratory results plus a listing of each bottle, its size and preservative. As well, the sampling date, sample location, preservative and chemical analysis were written on a white tape attached to the plastic bottle. All bottles used were plastic.

3.3.5 Sampling Frequency and Analysis

The sample shipments were generally received the next day (e.g. a Thursday sampling received Friday), but it occasionally took two days for receipt of the shipment. The sampling frequency was approximately weekly from March through June, whereafter a 10 to 14 day interval was used. After spring melt, samples were collected bi-daily for approximately a one-week period. This sampling frequency provided double the number of samples for which the project had budget. Due to the difference in cost of analyses between cation/anion parameters and radionuclides, the project was able to analyze individual weekly samples for cations and anions, but a composite for radionuclides. The composite was generally formed on a 50:50 basis of 2 successive samples. Thus, samples for cation/anion analyses were generally submitted to the laboratory in the plastic bottles filled in the field laboratory, whereas samples for radionuclide analyses were submitted in plastic bottles from two successive field samplings.

3.3.6 Laboratory Methods

Laboratory methods for chemical analyses used by the different laboratories are detailed in Appendix 5. Most of the cations were measured by Inductively Coupled Argon Plasma (ICAP) scan at Barringer Magenta while samples from January through March 1985, and check samples were measured by a Direct Current Plasma (DCP) analyzer at BEAK. Anions were measured by ion chromatograph at Barringer Magenta. Radionuclide analyses were carried out by Monenco Analytical Laboratories, while the check samples were analyzed by Chemex and Saskatchewan Research Council.

3.3.7 Analytical Results

Analytical results for the surface water streams SW-01, SW-02 and SW-03 are summarized on Tables 3.5 to 3.22. The results for the standard parameters have been divided into the five groups listed below. The sixth group give the results of the radionuclide analyses.

Group No.	Table No.	Parameters
1	3.5 to 3.7	Conductivity, acidity, pH, DO, Eh, temperature, TIC, TOC, NH_3
2	3.8 to 3.10	Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr
3	3.11 to 3.13	Cu, Fe, Fe^{2+}, K, Mg, Mn, Mo, Na, Ni, P, Pb
4	3.14 to 3.16	Se, Si, Sr, Th, Ti, V, Zn, Zr, lab cond, lab TDS
5	3.17 to 3.19	TKN, TP, F^-, Cl^-, NO_2^-, PO_4^{3-} , NO_3^-, SO_4^{2-}
6	3.20 to 3.22	U, Th-230, Ra-226, Pb-210, Po-210, Th-232, Ra-228, Th-228

In a one time sampling effort, surface water samples were collected at eight locations (SW-04 to SW-11) where water had ponded on the surface of the tailings during the spring melt. The samples were collected on 25 April during the spring melt. The results of these analyses are presented on Table 3.23.

3.3.8 Quality Assurance Results

Three forms of quality assurance results have been obtained. These included: measurements of non-radioactive parameters by two laboratories on the same sample, split in the field before shipment to the labs; measurements of non-radioactive parameters by one laboratory (Barringer Magenta) on a blind replicate sample (a sample split and submitted to the same laboratory); and measurements of radioactive parameters by one, two or three laboratories on blind replicates and split samples.

Results for the first type of QA testing, presented on Tables 3.24 to 3.27, include interlaboratory testing for non-radioactive parameters in samples collected on 15 April, 29 April and 19 July, and total inorganic carbon (TIC) in samples collected 1 August, 13 August, 29 August and 11 September. These are given as:

Table No.	
3.24	15 April sample for cations
3.25	25 April sample for cations
3.26	11-19 July composite for cations, anions, TKN and TP
3.27	TIC

Results of the blind replicate testing for non-radionuclide parameters are presented on Tables 3.28 and 3.29 for a composite of 25 and 31 July samples and a non-composite October sample. The results of the QA program for radionuclide testing, presented in Tables 3.30 to 3.34, include three laboratories (Monenco, SRC, Chemex) intercomparisons for an October sample and blind replicate testing of a July and October sample by one laboratory (Monenco). These results are given as:

Table No.	
3.28	For a 25/31 July composite for cations, anions, TP and TKN,
3.29	For an October sample,
3.30	25 March sample for radionuclides measured by three labs,
3.31	July sample for radionuclides measured by three labs,
3.32	October sample for radionuclides measured by three labs,
3.33	25/31 July composite submitted as a blind replicate,
3.34	Radionuclide Analysis of Blind Replicate for October Sample.

In addition to the above, QA results for the surface water samples from the Gunnar tailings area field study have also been included, as this information can be used to assess the quality of the data. The Gunnar QA data presented in Tables 3.35 and 3.36 includes duplicate analyses and blind replicate testing for non-radionuclide parameters, and duplicate analyses for radionuclides. The results are given as:

Table No.	
3.35	Duplicate analyses and blind replicate for 6 and 12 June samples for cations, anions for Gunnar surface water discharge,
3.36	Duplicate analyses for radionuclides from the Gunnar discharge.

To assess sample preservation techniques, various combinations of field filtering, acid preservation and subsequent laboratory filtering were tested in March, 1985. These results are given in Table 3.37 as: Study of Field and Laboratory Filtration.

3.3.9 Analyses of Results

In this section, a descriptive presentation of the chemistry of the surface streams is given, and a few points are made about the results of the quality assurance program.

Chemical Characteristics of Surface Water

Analysis of the chemical results shows that the dominant cations in the charge balance are iron and calcium. Aluminum, magnesium, and hydrogen ion also make significant contributions to the cation charge balance. The anionic charge balance is explained almost solely by sulphate ion. Due to the low pH (3-4), bicarbonate ion is negligible. For randomly selected samples, the charge balance for cations and anions are generally within 10% and typically 2-4%.

Acidity is a measure of the total base neutralizing capacity of the samples. It is a useful tool for summarizing the combined effects of Fe^{2+}, Fe^{3+}, and H^+ in the water samples. The acidity of the two seepage streams (SW-01; SW-02) is larger than for the pond outlet; this is reflected by the lower iron and sulphate concentrations in the pond outlet (SW-03). Also, the pH of the 2 seepage streams occasionally appears to be different from the pH of the pond outlet.

The pH is influenced by the oxidation state of iron and the quantity of iron. In the two seepage streams, Fe^{2+} constitutes in excess of 90% of Fe_T whereas it constitutes a varying percentage of Fe_T in the pond outlet. The effect of Fe^{2+} upon pH can be explained by the reaction:

$$4\ Fe^{2+} + O_2 + 10\ H_2O = 4\ Fe\ (OH)_3(s) + 8\ H^+$$

Fe^{2+} which seeps to the pond would cause a production of H^+ and hence a decrease in pH if iron (II) were oxidized. The exact pH change depends upon hydrolysis of other ions.

The calcium concentration in the pond outlet is smaller than in the seepage streams. The aluminum and potassium concentrations presumed to result from acid attack upon aluminosilicates (e.g. sericite) in the tailings are similar in all three streams. The differences in cation and anion concentrations may be due to different hydrological pathways (groundwater flow for the seepage streams, groundwater flow and surface water runoff for the pond) influencing the chemistry of the discharge water and possible different chemical dissolution mechanisms dominating in different parts of the tailings.

Most other parameters have concentrations in the sub-mg/L range (e.g. Ag, B, Ba, Be, Cd, Co, Dr, Cu. Mo, Ni, Pb, Sr, Th, Ti, V, Zn, Zr, F^-, NO_2^-, NO_3^-, TP, Br^-) with several being at the detection limit (Ag, Ni, Pb, V, NO_2^-, NO_3^-, Br^-). Several anions have a relatively poor detection limit (NO_2^-, NO_3^-, PO_4^{3-}) on the ion chromatograph due to sulphate interferences. The parameters As and Se, were generally at or near detection limit (1 ug/L).

Radionuclide parameters generally show an order of magnitude variation. Radionuclide values also have a wider range in interlaboratory comparison studies than cations. This wide range is thought to be due to sample preparation procedures.

The activity of U is less than that of Th-230 reflecting mill extraction of U. The activity of Th-230 is approximately an order of magnitude larger than that of its daughters Ra-226, Pb-210 and Po-120. The high activity of Th-230 could result from acid attack upon secondary thorium hydroxide precipitates found on the tailings solid phase and formed in the mill. It is not possible to analyze for a similar difference between Th-232/Th-228 and Ra-228 due to the high detection limit for Ra-228 in many samples, although the data suggest a similar range of values for Th-228/Th-232 and Ra-228.

Hydrological Effects

The hydrology of the streams had the following impact upon the chemical results:

i) The seepage streams (SW-01, SW-02) flowed at an approximately constant rate throughout the year with only a minor increase during spring melt. An exception is the elevated flow rate in SW-02 for a few days after April 22 due to overflow from the ponded water on the tailings surface.

A significant turbidity was observed during this short time period. Turbidity was not visible at other times in SW-02.

ii) The water flow of SW-03 is from a pond. This pond acts as a settling basin in which Fe^{2+} can be oxidized to Fe^{3+} and settle as iron hydroxide. The extent of coprecipitation and adsorption for removing other cations is unclear. The stream has substantially different concentrations of cations than the other two streams.

iii) SW03 was temporarily blocked by Rio Algom for a period from late April through early June to prevent the pond from discharging. This action was taken to aid hydraulic control of downstream ponds which were flooding. Water continued to flow through the barrier, but at a small rate. Water which seeped through the barrier had substantially lower concentrations of cations because of adsorption by the barrier material. Samples for chemical analyses were initially taken downstream of the barrier after placement of the barrier but subsequently just upstream of the barrier. These upstream samples thus represent the pond's characteristics and the material exported from the pond.

Cation-Anion Balance

The ions aluminum, calcium, ferrous and ferric iron, magnesium, hydrogen and sulphate generally give the largest contribution to the charge balance of the environmental sample. For these components, the electrical charge on cations was compared to that of anions. The total cation charge typically varies from being 15% larger to 5% smaller than the total anion charge. More detailed results are given in Appendix 5.

Ideally, one desires a charge balance which is within 2-5% (cations compared to anions). This will result, only if the measurement is made upon the same bottle and same filtered sample. But this procedure was generally not used in this study. Different preservation methods were used for different parameters. Also, there was a time difference between collection and analysis for the different parameters. Fe^{2+} was analyzed within four hours of sample collection. A sample for cation analysis was preserved and analyzed within the recommended holding time (six months). But the sample for anion analysis was not preserved and was analyzed within a timeframe which exceeded the recommended holding time (one week).

These calculations of charge balance have ignored the hydrolysis of aluminum and iron species, and the formation of sulphate complexes with calcium, magnesium, iron and sulphate. The hydrolysis of aluminum will be negligible in the pH range of 3.2 to 4 because the pk (= 5.1) for the $Al(H_2O)_6^{3+}$ - $Al(H_2O)_5OH^{2+}$ reaction means that aluminum will not start to hydrolyze significantly until a pH of greater than 4.5. Similarly, Fe^{2+} will not hydrolyze significantly until pH = 8. But, Fe^{3+} hydrolyzes at pH values greater than 2.2, and iron III polymers and precipitates can form in the pH 3 to 4 range if iron II is oxidized to iron III. The formation of sulphate complexes will not cause a significant error in calculation of overall charge balance.

Of the total charge balance, calcium and iron constitute 60 to 75% of the total cation charge, with the remainder divided among aluminum, magnesium and hydrogen. The contribution to charge by hydrogen ion is generally less than that of aluminum and magnesium. Accordingly, the main errors in charge balance will be due to:

- imprecise knowledge about the hydrolytic state of Fe^{3+}, and
- errors in measurement of Fe, Fe^{2+}, Ca and sulphate

Errors in the anion analyses could result from the effects of evaporation, adsorption of sulphate to the sides of the plastic bottle or entrapment onto the ferric hydroxide precipitate. None of these are expected to cause a significant error. At the sulphate levels present, adsorption onto the plastic bottle will be minimal. As well, emeshment of sulphate into a ferric colloid which coagulates should be minimal because sulphate is an outer orbital complex which should be released quickly during coagulation. Measurement of samples filtered at different times after field sampling (0.45 um filter) did not show a significant difference (e.g. see Table 3.37).

3.3.10 InterlaboratoryComparisons for Non-Radionuclide Parameters (see Table 3.24 to 3.26)

The interlaboratory comparison concentrated upon cations. For major cations, the two laboratories (ICAP-Barringer, DCP-BEAK) agree to within approximately 10% for most parameters and samples. In many cases, the agreement is within 2 to 3%. For minor cations in the sub-mg/L range, the agreement is also good for some cations (e.g. Ba, Sr), but poor for others. The differences in agreement for these cations results partly from differences in detection limits for parameters such as Mo. For others, such as Co, ICAP is higher than the DCP for one set of samples (e.g. 29 April), but close for another set of samples. These differences may be due to calibration problems on a particular day.

In the sub-mg/L level, the DCP appears to give biased high results for Cr and Pb. Similar results are observed in the Gunnar water samples. This is attributed to a possible sulphate interference with the DCP instrumentation and has been noted by other DCP users. However, the ICP appears to give low values for Pb in the sub-mg/L range (see Appendix 5).

A more limited interlaboratory comparison was made for anions and other parameters. The differences between measured sulphate concentrations varies from 4% to 25%. The value for chloride and fluoride by BEAK are approximately double those of Barringer. The nitrate and phosphate parameters are below the detection limit, although the detection limit of Barringer's ion chromatograph is somewhat better than that of BEAK. In the anion scan, the poor detection limit for nitrate, phosphate and nitrite is caused by tail of the sulphate peak interfering with the nitrate, nitrite and orthophosphate peaks.

The comparison of total kjeldahl nitrogen (ammonia + organic N) varies from 9% to 30%. The comparison for total phosphorus is unsatisfactory because of recovery problems by the check laboratory. The measured values for nitrate by wet methods (11 & 19 July, Table 3.26) are high because of interference by Fe^{2+} and Fe^{3+}. The values for nitrate from the ion chromatograph are judged to be most appropriate, although the results are unsatisfactory because actual values in the ug/L range were desired.

The comparison of TIC measurements (Table 3.27) made by the BEAK laboratory and a check laboratory shows an agreement within 20% for many samples, but differences up to 100% for others. A similar principle is used by the two laboratories for the measurement, but different instruments. There is no obvious systematic bias.

Blind Replicate and Laboratory QC Replicates

Blind replicates for Barringer (Table 3.28 and 3.29) generally agree within 2 to 3% or better. There is the odd discrepancy such as B and Mo for the SW-02 sample on 25-31 July. A similar agreement is observed for laboratory QC replicates. A similar agreement is observed for blind replicates and laboratory QC replicates for the Gunnar surface water samples (Tables 3.35 and 3.36).

3.3.11 Interlaboratory Comparisons for Radionuclide Parameters

Interlaboratory comparisons (see Tables 3.30 to 3.31) were done by two laboratories: Monenco as the prime laboratory, and Chemex as the main check laboratory. Because a first interlaboratory comparison, which used three laboratories (SRC as the third) showed substantial variation (Table 3.30), the use of two check laboratories was continued in a later comparison (Table 3.31). Interlaboratory comparisons for Gunnar (Table 3.36) used Monenco and SRC.

Values for uranium are quite close (10%).

Values for Th-230 are generally within 20%, but values for Ra-226, Th-232 and Th-228 showed up to an order of magnitude difference in the March interlaboratory comparison. There is no obvious systematic bias for thorium. The relative differences in thorium measurements are unexpected if there is systematic bias because a common tracer and common concentration-precipitation steps are used for measurement of all three thorium parameters. Because these results were unsatisfactory, all results (Table 3.30, Table 3.36) were tabulated and forwarded to the three laboratories without identifying the other laboratories. They were asked to check for transcription or calculation errors. Only one transcription error for an uranium value was found. One laboratory repeated their analyses for Ra-226 and thorium parameters (the one with the low values for Ra-226 and Th-232/Th-228) and found the initial results to be satisfactory and hence stood by them. This laboratory also offered some plausible explanations for the differences. The other laboratories suggested reasons for the differences, but did not have sufficient sample to re-analyze their samples.

The results of the initial interlaboratory comparison (Table 3.30) should be viewed in conjunction with the Gunnar interlaboratory comparison (Table 3.36). All samples (SW-01 25 March, SW-01 29 March, SW-02 March of Table 3.30; SW-C1 March, SW-C2 March, SW-03 March of Table 3.36) were submitted together. The 6 samples sent to Chemex and SRC were sent out as one lot, while the 6 samples sent to Monenco were submitted in the middle of a group of experimental solutions which contained the following typical levels of radionuclides; U:3.6 - 9500 ppm, Th-230: 2.8 - 9800 Bq/L; Ra-226: 2.7 - 2200 Bq/L; Pb-210: 3.5 - 950 Bq/L; Po: 13-400 Bq/L; Th-232: 2-400 Bq/L; Ra-228: 7-5600 Bq/L; Th-232: 2-400 Bq/L.

In response to our inquiry, two laboratories (Chemex, Monenco) wrote back detailed responses while one telephoned a response (no transcription errors). These are now summarized. Monenco made the following points in a 14 June 1985 letter.

(i) The uranium and Th-230 results are in very good agreement

ii) In view of the good agreement, it is surprising that the Th-232 and Th-228 results are not as good. With alpha spectometry, high Th-230 and inadequate resolution can contribute to higher Th-232 results if the tailing of the Th-230 alpha peak is not properly taken into consideration. Monenco had the lowest values of all the laboratories. They re-examined all their spectra and were satisfied that their contributions were properly considered.

iii) The Ra-226 results were 'certainly' surprising. The Ra-226 results for three samples (the Gunnar samples) were 'very good' while the results for the other three samples (the Lacnor samples) were 'poor'. They rechecked their calculations, their quality control, and reran all six samples and found that these new results agreed with the original report (the data given in Tables 3.30 and 3.36).

Monenco discussed the possible causes of the differences with the general tenor of the discussion centering upon the presence of Ra-224 in the Lacnor samples and its influence upon the measure of Ra-226. In the Lacnor samples, there was a large amount of unsupported Ra-224. Because Ra-224 is relatively close to Ra-226 in terms of energy, this could contribute to measured Ra-226 activity. Monenco suspected that the agreement for the Gunnar samples probably resulted from the absence of Ra-224 and Ra-223 in these samples.

Chemex made the following points in their letter.

i) Data uncertainty were not reported in the letter sent to the three labs. Given the uncertainty of the counting statistics for Ra-228 for example of ± 0.2 Bq/L, the data of SRC and Chemex agree.

ii) Larger sample volume was desirable for the check laboratories because with the number of analyses requested, only a small volume was available for each radionuclide. With an error of a few counts and high volume factors, a relatively high uncertainty resulted.

iii) The presence of fine particulate and colloidal matter will result in analytical problems.

   a) The samples were analyzed on a total basis which means that no filtration was carried out after sample collection. The presence of fine particulate and colloidal matter can easily result in significant sample inhomogeneity in samples sent to different laboratories, irrespective of the care employed in the mixing and subdividing the original samples. This effect would be very important because it is well known that the colloidal size fraction contains substantial activity.

b) Despite acid preservation, precipitation of some amount of an iron compound must have occurred in their aliquot of SW-02 (March 25) because a yellowish compound was visible in the bottom of a bottle. This would contribute to sample variability by scavenging radionuclides and suggests the need to check on sample preservation techniques. (Aside: the presence of these precipitates may not have biased Chemex's results significantly because their results agree with SRC's analyses and their values are higher than those of Monenco. If precipitates biased the results, their values should be the lowest of all labs).

iv) Chemex determined Ra-226 by alpha spectroscopy, but the same precipitate (formed by sampling procedures) was also counted by gross alpha techniques. The two data sets were in 'good agreement'.

v) Th-232 and Th-228 activities have a large uncertainty associated with them because they gave a very small number of counts. Chemex would ideally have desired more sample so that the counts can be checked by colorimetry for the analysis.

vi) Chemex's value for Th-230 for SW-01 29 March (their value was 4.2 Bq/L compared to 7.5 and 6.85 Bq/L from the other two laboratories) could be low due to alpha spectra degradation caused by coprecipitation of other elements. They were working on procedures to improve the spectra by cleaning up the sample with ion exchange techniques.

SRC stated (via a telephone conversation) that there were no transcription errors in their data. They also felt that the agreement between their results and that of at least one other laboratory (unnamed in correspondence to the 3 labs at that date) was 'good' where 'good' was judged by the criteria of being

20% to 30% apart.

As a result of this correspondence, a series of telephone calls were made to the different laboratories to inform them of the general results of the correspondence and to seek further opinions upon the cause of discrepancy particularly between Ra-226 and thorium parameters since each laboratory was using essentially the same analytical technique. The only difference in techniques was use by Monenco of High Resolution alpha spectroscopy which is essentially use of a smaller amount of chemical to coprecipitate thorium and radium to achieve sharper spectra for counting. The general hypothesis developed by Monenco was that the differences must be due to laboratory sample preparation techniques and the influence of colloidal material upon recoveries. Such colloidal material would probably not influence the recoveries calculated for the tracer used in the sample preparation techniques.

As a result of this correspondence, it was decided to add more nitric acid to samples for radionuclide analysis immediately after field sampling. Also before shipment of radionuclide samples for analysis from BEAK, all samples for radionuclide and cation analyses were visually inspected to ascertain that there was no precipitate present. In a few samples, it was observed that small quantities of approximately 0.1 mm-sized particles were present in the bottom of the sample bottle after arrival from the field laboratory. More nitric acid was added to the sample and the sample allowed to stand overnight. In most cases, these small precipitates dissolved, reflecting the solubility of Fe(III) at lower pH. If the precipitate did not dissolve, the sample was rejected for chemical analysis.

In the next set of samples (Table 3.31), results of the QA audit for all three laboratories show a narrower range for Ra-226 and thorium parameters although the range is still unsatisfactory for Ra-226, Th-232 and Th-228. For Th-230, the three laboratories agree for SW-01, but SRC's values are 50% of Chemex for SW-02, and Chemex's values are double those of Monenco and of SRC for SW-03. For Ra-226, the three labs agree for SW-02, but Chemex is intermediate between

Monenco and SRC for the other two samples. For Th-232 and Th-228, Chemex has exactly the same values for both isotopes while the other labs show some differences. SRC generally has the highest values which Monenco either agrees with the values of the other laboratories or is intermediate between the two other laboratories.

A laboratory audit involving submission of knowns within a ferrous sulphate matrix typical of Lacnor runoff, was initiated later in the program. Its results are discussed in Appendix 5.

The interlaboratory comparison for Ra-228 showed unsatisfactory results with the first set (Tables 3.20, 3.30) with differences of up to five times for Lacnor and ten times for Gunnar. The high values were subsequently resolved as being erroneous because the laboratory thought that they had a better detection limit than actually occurred. This problem is possibly due to the March 1985 samples (Tables 3.30, 3.36) being analyzed in the middle of a group of experiments which contained substantial levels of Ra-228.

A limited interlaboratory comparison is given in Table 3.32 for Pb-210.

Blind Replicates and Laboratory QC Replicates for Radionuclides

The analysis of blind replicates made by Monenco (Table 3.33 and 3.34) show a much narrower range than the interlaboratory comparison. The results also show unsatisfactory detection limits for the counting by beta spectroscopy for Pb-210 and Ra-228. Factors affecting the detection limit include:

- the beta counter having a background count which is approximately 20 times that of alpha spectroscopy, and
- not using a large enough sample for counting.

3.3.12 Chemical Precipitation in Surface Water Samples

The surface water of Lacnor typically has a pH around 3 to 4. The two seepage streams have higher iron concentrations than the pond outflow. Most of the iron in the seepage streams is Fe^{2+}. Because there was evidence in the first unpreserved sample bottles (January 1985) that iron was precipitating, a special study was undertaken in late February to ascertain the extent of precipitation and its effect upon other ions.

The results are given in Table 3.37 for the three surface water streams, SW-01, SW-02 and SW-03. Each sample was subjected to a series of treatments in the field and/or the lab. They are as follows:

1) Field filtered and unpreserved.
2) Field filtered and preserved with nitric acid.
3) Field filtered and preserved with sulphuric acid.
4)a Not filtered in the field, but filtered in the lab and analyzed.
4)b Not filtered in the field, and acidified prior to total analyses.

The first sample provides information on the extent of precipitation after filtration during sample shipment in comparison to sample 4b. Cation analysis on samples 2 and 3 provide information on differences in preservation. Sample 4a provides information on total precipitation while comparison of sample 1 and 4b provides information on the extent of precipitation before field filtration. The data indicated the following:

i) Nitrate measurements by wet methods were in the mg/L range. Such values are typical of surface water runoff from agricultural watersheds. But iron interference in this method and generally lower values measured by ion chromatography suggest that these values are erroneous and that nitrate values are generally lower than 0.02mg/L.

ii) Total phosphorus concentrations, made by wet methods, are of the order of 0.1mg/L whereas ion chromatography analyses for orthophosphorus made later in the program by Barringer have a detection limit of 0.1 or 1 mg/L. There were few interferences detected during analysis of the data of Table 3.37. Using similar analytical techniques, the data of

Barringer (Table 3.28), obtained later (May-September, 1985) in the sampling program indicate a range of 30-90 mg/L for total phosphorus. Good estimates of phosphorus levels in the tailings runoff are needed to aid interpretation of thorium transport because phosphorus complexes strongly with metals such as thorium. But this program did not maintain a continuous analytical program for phosphorus due to potential interferences from blanks and other causes. For example, during analysis for TP, it was observed that the colour of the blank was lower than that developed for surface water samples from other environments (e.g. lakes). Whether iron also interferes with the complexing process is unclear.

iii) The conductivity measured at the laboratory (20°C) is substantially less than that measured in the field. (See Tables 3.5 to 3.30.) Thus laboratory measurements of conductivity will be erroneous.

iv) Most of the kjeldahl nitrogen (ammonia plus organic N) is ammonia. Ammonia will be formed by hydrolysis of organic nitrogen under conditions of sulphuric acid preservation. Hence the data does not preclude the presence of organic nitrogen in the original samples. However, laboratory measurements of ammonia on samples preserved with acid provide a reasonable estimate of kjeldahl nitrogen.

v) Sulphate values for SW-02 are the same for filtered and unfiltered samples within the accuracy of the data.

vii) There was not a substantial portion of metals removed by filtration. Within the variability of the data, the iron concentration of filtered samples is the same as unfiltered samples.

viii) Addition of the prescribed amount of nitric acid in the field is adequate for preservation purposes. It lowers the pH from the environmental pH range of 2.9 to 3.8 to 1.3 to 1.5 for preservation.

ix) Most of the iron in the sulphuric acid preserved sample from the two seepage streams (SW-01 and SW-02) is Fe^{2+}.

3.3.13 Discussion of Interlaboratory Comparisons

A comparison of the chemical analysis for cations and anions with the measurement of the activity of radionuclides suggests that the between laboratory, and within -laboratory variance is smaller for cations and anions than for radionuclides. Because the counting statistics for radionuclide measurement are generally as good as the measurement statistics for cations and anions, the major differences are thought to be due to preparation procedures. Radionuclide measurement of liquid samples involves sample precipitation-concentration-purification steps.

Cation (ICP/DCP/AAS) or anion measurements, on the other hand, are generally direct. Accordingly, one might expect a lower method variance. This will, however, occur only when a constituent can be measured free of interferences. Standards for samples are generally based upon pure solutions, or on a set of standards with a known matrix. Evaluating the level of a constituent which has a different matrix (of other constituents) can lead to erroneous results. For example, calcium may have an absorption or emission peak at the same place on the spectrum as lead. At certain concentration levels, calcium may interfere by artificially increasing the value of the peak above that caused by Pb. Then, chemical measurement of Pb is either not possible or requires the analyst to choose a secondary wavelength of lead for analyses - such a wavelength may be much less sensitive and/or have its own interferences. Use of the method of standard additions is often required to resolve the proper value for Pb and to determine the degree of interference by calcium. Such an evaluation will be specific to the matrix involved.

TABLE 3.5: SURFACE WATER - GROUP 1 PARAMETERS, SITE SW-01

Date (1985)	Cond. (µS/cm)	Anal. Temp.(1) (°C)	Acidity (mg/L)	pH	DO (mg/L)	Eh (mV)	Insitu Temp. (°C)	TIC (mg/L)	TOC (mg/L)	NH3 (mg/L)
Feb 18-22			1,950	3.8				1.0	9.0	4.2
Mar 12	18,000	13	950	3.65			2	2.5	3.0	6.0
Mar 18	19,500	2	1,320	3.75			0			
Mar 21	20,000	8	1,230	3.85			1	30	3.0	34
Mar 25	20,000	12	1,120	3.5			0	2.0	5.4	88
Mar 29	11,500	12	560	3.25			1	1.5	3.0	8.0
Apr 03	16,500	6	1,070	3.35			1			
Apr 15	13,500	14	606	3.15			2			
Apr 18	10,800	2	399	3.2			2			
Apr 22	11,600	20	365	3.15			4			
Apr 25	15,500	18	598	3.05			7			
Apr 26	16,000	17	682	3.1			6			
Apr 29	18,500	4	825	2.95						
May 02	18,000	13	857	3.35						
May 06	16,000	10	709	3.45			5			
May 09	19,000	15	804	3.45			6			
May 13	18,000	13	846	3.4			9			
May 22	21,400	16	899	3.35			7			
May 30	18,500		1,120	3.3			9			
Jun 10	22,000	18	952	3.2			11			
Jun 19	20,000	21	1,110	3.05			17			
Jun 27	24,000	21	1,340	3.30	5.1	375	11			
Jul 05	21,000	18.5	1,330	3.5	5.1	355	12			
Jul 11	27,000	15	1,590	3.3	5.4	335	10			
Jul 18	29,000	17	1,410	3.45	-	330	12			
Jul 25	22,000	19	1,150	3.1	-	420	14			
Jul 31	30,500	19	1,600	3.4	5.3	325	11	6.5	-	
Aug 13	22,800	15	1,500	3.2	5.1	395	13	10	4	
Aug 29	23,600	13	2,700	3.4	5.6	365	12	19.5	3	
Sep 11	20,000	9	1,810	3.5	6.6	360	7	9.5	-	
Oct 09	21,000	9	1,500	3.25	5.8	380	8	13	6	
Oct 31	21,000	7	1,850	3.65	4.8	370	3	-	-	

Note:

1) Temperature at time of analysis.

TABLE 3.6: SURFACE WATER - GROUP 1 PARAMETERS, SITE SW-02

Date (1985)	Cond. (µS/cm)	Anal. Temp. (°C)(1)	Acidity (mg/L)	pH	DO (mg/L)	Eh (mV)	Insitu Temp. (°C)	TIC (mg/L)	TOC (mg/L)	NH3 (mg/L
Jan 23			2,640	3.2				1.5	10	6.7
Mar 12	31,700	14	1,970	3.35			1.5	1.0	5.0	
Mar 18	29,000	1	2,500	3.45			0			
Mar 21				-						
Mar 25	29,000	12	2,320	3.35	-		1	1.0	4.0	160
Mar 29	27,000	12	1,680	3.40			0	2.0	5.0	56
Apr 03	27,000	6	2,050	3.2			0			
Apr 15	28,000	14	1,470	-			2			
Apr 18	20,500	2	1,020	3.2			2.5			
Apr 22	17,200	20	492	3.2			8			
Apr 23	-									
Apr 24	-									
Apr 25	17,000	20	603	3.2			9			
Apr 26	13,500	17	560	3.3			7			
Apr 29	12,200	5.5	476	2.95						
May 02	13,000	13	487	3.0						
May 06	12,400	12.5	518	3.15			7			
May 09	14,000	15	550	3.2			7			
May 13	15,500	13	645	3.1			12			
May 22	18,000	16	794	3.00			14			
May 30	17,500	-	958	3.1			11			
Jun 10	23,800	21	1,100	2.85			22			
Jun 19	32,000	21	1,980	3.00			22			
Jun 27	40,000	22	2,520	3.00	4.5	375	20			
Jul 05	39,000	21	2,850	3.3	4.6	360	15			
Jul 11	43,000	20	3,220	3.05	4.5	355	17			
Jul 18	38,700	18	2,710	3.25	-	350	9			
Jul 25	35,200	18	1,820	2.95	-	400	16.5			
Jul 31	40,000	20	2,800	3.15	5.2	340	13	<0.5	-	
Aug 13	38,000	17	2,690	3.1	4.7	380	15	2.0	4.5	
Aug 29	41,000	13	3,290	3.15	6.4	360	12	3.0	4.0	
Sep 11	31,000	8	3,510	3.4	8.0	360	7	2.0	-	
Oct 09	38,000	11	3,050	3.3	7.8	370	9	2.0	6.0	
Oct 31	35,500	5	3,260	3.45	8.8	360	1			

Note:

1) Temperature at time of analysis

TABLE 3.7: SURFACE WATER - GROUP 1 PARAMETERS, SITE SW-03

Date (1985)	Cond. (µS/cm)	Anal. Temp (°C)(1)	Acidity (mg/L)	pH	DO (mg/L)	Eh (mV)	Insitu Temp. (°C)	TIC (mg/L)	TOC (mg/L)	NH3 (mg/L)
Jan 23			500	2.9			0	1.5	4.0	1.58
Mar 12	12,800	15	340	2.95			0	1.0	2.5	1.43
Mar 18	9,900	3	520	3.05			0			
Mar 21	12,300	9	508	2.90			0	1.5	1.0	5.5
Mar 25	10,900	12	550	2.95			0	1.0	1.0	5.2
Mar 29	10,500	12	490	3.00			0	2.0	3.0	3.8
Apr 03	8,200	6	423	3.2			0			
Apr 15	8,800	14	370	-			0			
Apr 18	7,500	2	270	3.2			0			
Apr 22	5,400	20	143	3.4			0			
Apr 23	3,600	7	-	3.75			1			
Apr 24	1,000	12	-	5.40			2			
Apr 25	1,400	20	-	4.3			-			
Apr 26	1,100	17	40	4.3			3			
Apr 29	2,050		42	-			3			
Apr 29^A	2,400	6	58	3.7			3			
May 02	-		418	3.2						
May 02^A	3,400	13	74	3.1						
May 06	2,300	10	69	3.75			6			
May 06^A	3,700	10	100	3.5			8			
May 09	3,400	17	64	3.35			9			
May 09^A	4,800	15	106	3.4			6			
May 13	4,400	14.6	95	3.35			15			
May 13^A	5,700	13	122	3.25			15			
May 22	5,100	16	127	3.25			10			
May 22^A	7,600	16	179	3.05			15			
May 30	7,900	-	138	3.0			-			
Jun 10	7,500	18	222	3.1			18			
Jun 10^A	10,200	18	265	2.85			17			
Jun 19	10,600	21	422	2.85			16			
Jun 19^A	10,700	21	433	2.80			16			
Jun 27	10,300	20.5	379	2.95	5.8	495	15			
Jul 05	8,000	20.5	357	2.95	4.4	480	17			
Jul 11	9,100	18	400	2.90	6.2	480	14			
Jul 18	7,800	19	173	3.20	-	410	11			
Jul 25	8,500	19	162	3.05		475	17			
Jul 31	8,900	20	227	3.00	4.2	430	15	1.0	-	
Aug 13	13,200	17	465	2.85	4.9	530	17	2.0	<0.5	
Aug 29	14,900	16	660	2.85	5.6	515	14	4.0	<0.5	
Sep 11	11,500	11	454	2.95	8.4	510	9	1.5	-	
Oct 09	8,200	11	335	3.0	7.9	585	9	5.5	0.5	
Oct 31	12,800	7	346	2.90	9.8	510	1	2.0	<0.5	

Note:

1) Temperature at time of analysis
2) "A" is alternative sampling location (upstream of barrier)

TABLE 3.8: SURFACE WATER - GROUP 2 PARAMETERS, SITE SW-01

Date (1985)	Ag mg/L	Al mg/L	As ug/L	B mg/L	Ba mg/L	Be mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L
FEB 18-22		20	4/3	0.50/.55	.01	<.01	310	0.23	0.28	.05
MAR 12	0.01	19.5	2	0.23	.01	<.01	220	.11	.24	.03
MAR 18	.01/.01	22	4	0.31	.01	<.01	287	.18	.23	.04
MAR 21	.01/.01	19.2	<1	0.29	<.01	<.01	230	.19/.26	.23/.24	.05/.05
MAR 25	.01	18.2	6/8	0.26	<.01	<.01	220	.17/.23	.23/.26	.05/.08
MAR 29	<.01/<.01	13.3	4	0.09	<.01	<.01	103	.06	.13	.02
APR 03	<.1	29.5	9	.915	.008	.0025	229	<.01	.20	<.01
APR 18	<.005	16.0		<.004	.010	.0010	109	.02	.13	.02
APR 22	<.005	18.3		<.004	.012	.0011	133	.01	.14	.03
APR 25	<.005	28.1	<1	.345	.010	.0019	173	<.01	.24	<.01
APR 26	<.005	32.2	1	.419	.008	.0023	200	.01	.28	<.01
APR 29	<.005	38.6	1	.603	.007	.0028	250	.02	.34	.01
MAY 02	<.005	36.9	1	<.004	.005	.0022	255	.03	.29	.07
MAY 06	<.005	31.0		<.004	.006	.0019	233	.02	.28	.04
MAY 09	<.005	33.0		<.004	.006	.0022	254	.03	.27	.06
MAY 13	<.005	33.4	1	<.004	.005	.0021	276	.02	.29	.06
MAY 22	<.005	31.7		<.004	<.005	.0019	315	.03	.24	.04
MAY 30	<.005	31.5	1	<.004	<.005	.0019	313	.03	.27	.04
JUN 10-19	<.005	28.6	<1	.018	<.005	.0016	336	<.01	.27	.19
JUN 27-JUL05	<.005	26.3	<1	.017	<.005	.0015	380	<.01	.23	.23
JUL 11	<.005	26.8	<1	.011	.005	.0015	401	<.01	.23	.27
JUL 25	<.005	31.7	2	.213	.011	.0020	310	<.01	.31	.32
JUL 31	<.005	31.0	2	.200	.012	.0020	316	<.01	.33	.31
AUG 29	<.005	22.9		<.004	.007	.0019	354	.04	.17	.03
OCT	<.005	23.3		<.004	.007	.0019	296	.02	.17	.06
OCT(DUP)	<.005	22.6		<.004	.005	.0017	290	.03	.16	.06

TABLE 3.9 SURFACE WATER - GROUP 2 PARAMETERS, SITE SW-02

Date (1985)	Ag mg/L	Al mg/L	As ug/L	B mg/L	Ba mg/L	Be mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L
JAN 23		14.2/18.2	<1/ <1	1.40/1.45	.02/.01	<.01/.01	390/410	.07	0.07	.07
FEB1 8-22										
FILTERED[1]	.02	13.7	1.0/2	0.9	.01	<.01	390/380	.43	.44	.07
UNFILT./FILT.[1]	.02	14.8	2	0.68	.08	<.01	400	.40	.44	.06
TOTAL[1]	.02	14.3	6	0.66	.01	<.01	370	.40	.44	.07
MAR 12	.02	11.6	4	0.51	.01	<.01	290	.29	.31	.04
MAR 18	.01	12.6	4	0.57	.01	<.01	340	.37	.36	.06
MAR 25	.01	12	<1	.54	<.01	<.01	320	.41/.48	.36/.36	.06/.04
MAR 29	.01	10	4	.38	<.01	<.01	220	.29/.38	.27/.29	.06/.04
APR 03	<.005	18.0	1	2.03	<.005	.0021	273	<.01	.19	<.01
APR 22	<.005	9.95		<.004	.012	.0011	116	.02	.15	.04
APR 26[2]	.007	.62	<1	<.004	.010	<.0005	7.06	<.01	.07	<.01
APR 29 UN	.005	10.1	1	.391	.012	.0011	102	<.01	.20	<.01
MAY 02	<.005	10.3	1	<.004	.009	.0007	111	.01	.14	.02
MAY 06	<.005	10.8		<.004	.010	.0010	118	.02	.16	.05
MAY 09	.007	11.6		<.004	.010	.0010	129	.02	.18	.06
MAY 13	<.005	13.1	<1	<.004	.010	.0012	148	.02	.21	.04
MAY 22	<.005	14.3		<.004	.008	.0012	176	.02	.21	.06
MAY 30	<.005	14.6	1	<.004	.006	.0010	195	.02	.16	.03
JUN 10-19	<.005	18.3	<1	.045	.006	.0013	267	<.01	.25	.29
JUN 27-JUL05	<.005	18.2	1	<.004	.009	.0013	381	<.01	.29	.51
JUL 11	<.005	17.7	<1	<.004	.008	.0013	407	<.01	.29	.57
JUL 25	<.005	16.9	1	.300	.008	.0013	362	<.01	.29	.57
JUL 31	<.005	16.6	1	.205	.008	.0011	352	<.01	.26	.54
AUG 29	<.005	16.5		<.004	.010	.0022	400	.04	.21	<.01
OCT	<.005	18.7		<.004	.006	.0021	387	.04	.21	<.01
OCT(DUP)	<.005	18.4		<.004	.010	.0023	386	.05	.23	<.01

Notes

1) See Table 3.37 for description of terminology
2) Values appear in error but were verified by laboratory

Table 3.10 - SURFACE WATER GROUP 2 PARAMETERS, SITE SW-03

Date (1985)	Ag mg/L	Al mg/L	As ug/L	B mg/L	Ba mg/L	Be mg/L	Ca mg/L	Cd mg/L	Co mg/L	Cr mg/L
JAN 23	<.01	8.8	2.0	0.4/.35	.01/.01	<.01	60/52	.03/.031	.12	.03
FEB 18-22 Fil[1]	<.01	13.2	2.0	0.2	.01	<.01	91	.04	.18	.04
MAR 12	<.01	12.5/12.4	6	.08	<.01	<.01	85/78	.06/.05	.19/.18	.05
MAR 18	<.01	12.2	8/8	0.09	.01	<.01	87	.035	.16	.04
MAR 21	.01/.01	9.4	10	.08	<.01	<.01	67	04	.15	.03
MAR 21 FIL	<.01	10.7	-	-	.02	<.01	85	.025/.030	.17/.16	.04
MAR 25	.01	9.5	4	.09	<.01	<.01	79	.05	.15	.04
MAR 25 FIL	<.01	10.4	-	-	.01	<.01	80	.02	.15	.04
MAR 29	<.01	8.1	4/8	.07	<.01	<.01	61	.065	.13	.03
MAR 29 FIL	<.01	9.0	-	-	.01	<.01	69	.02	.13	.03
APR 03	<.005	8.23	2	.272	.010	.0007	61.9	<.01	.16	<.01
APR 03 FIL	<.005	8.26	1	.275	.011	.0007	61.0	<.01	.14	<.01
APR 15 FIL	.005	7.79		<.004	.009	.0005	60.6	<.01	.11	.03
APR 18 FIL	<.005	5.52		<.004	.009	<.0005	47.9	<.01	.07	.02
APR 23	.006	2.52	1	.072	.011	<.0005	32.0	<.01	.05	<.01
APR 24	.005	.49	<1	<.004	.009	<.0005	5.33	<.01	.06	<.01
APR 25	<.005	.41	<1	<.004	.010	<.0005	5.84	<.01	<.05	<.01
APR 26	<.005	11.7	3	.472	.015	.0011	107[3]	.01	.14	<.01
APR 29[2]	<.005	1.15	<1	.025	.008	<.0005	15.4	<.01	.06	<.01
APR 29 Fil[2]	.005	1.17	<1	.028	.008	<.0005	15.3	<.01	.06	<.01
MAY 02[2]	<.005	1.52		<.004	.006	<.0005	20.3	<.01	<.05	<.01
MAY 06[2]	.010	1.76		<.004	.009	<.0005	22.9	<.01	.06	<.01
MAY 09[2]	<.005	2.26		<.004	.008	<.0005	27.7	<.01	.06	<.01
MAY 13[2]	<.005	3.00		<.004	.009	<.0005	32.9	<.01	.12	<.01
MAY 22[2]	<.005	4.20		<.004	.011	<.0005	40.2	<.01	.12	.02
MAY 30[2]	<.005	4.89		<.004	.011	<.0005	44.5	<.01	.11	.01
JUN 10-21[2]	<.005	6.74	<1	<.004	.010	<.0005	57.5	<.01	.17	.04
JUN 27-JUL 05	<.005	9.73	<1	<.004	.019	<.0005	53.8	<.01	.13	.03
JUL 11	<.005	9.40		<.004	.030	<.0005	50.1	<.01	.10	.02
JUL 25	<.005	7.66	<1	<.004	.025	.0006	46.4	<.01	.15	.02
JUL 31	<.005	7.65	<1	<.004	.025	.0007	46.5	<.01	.10	.02
AUG 29	<.005	12.2		<.004	.022	.0009	71.1	<.01	.17	.05
OCT	<.005	11.1		<.004	.014	.0009	77.1	<.01	.20	.06
OCT(DUP)	<.005	10.6		<.004	.014	.0008	72.2	<.01	.18	.06

Notes

1) See Table 3.37 for description of terminology
2) Alternative sampling location upstream of barrier
3) Values appear in error but were verified by laboratory

Table 3.11 - SURFACE WATER - GROUP 3 PARAMETERS, SITE SW-01

Date (1985)	Cu mg/L	Fe mg/L	Fe2+ ug/L	K mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	P mg/L	Pb mg/L
FEB 18-22	0.11	800	780	15.9	53	3.6	.12	10.4	.27	-	0.42
MAR 12	.22	490	420/450	10.2	34	2.1	.07	6.9	.23	-	.33
MAR 18	.085	630	600	13.1	45	2.4	.11	9.1	.23	-	.36
MAR 21	.11/.09	620	603	12.4	40	2.1/2.3	.08	8.7	.23/.15	-	.35/.33
MAR 25	.16/.15	550	531	10.5	36	1.89/2.0	.08	7.7	.22/.16	-	.38/.50
MAR 29	.19	169	200	4.2	15.7	.81	.04	3.5	.12	-	.22
APR 03	.153	386	390	6	32.6	1.69	<.2	3	.21	<.5	<.05
APR 15			168								
APR 18	.114	96.0	98	3	12.6	.52	<.2	2	.13	<.5	<1
APR 22	.132	73.7	56	2	12.0	.49	<.2	1	.14	<.5	<1
APR 25	.199	134	112	3	18.6	.85	<.2	2	.20	<.5	<.05
APR 26	.213	168	130	4	21.4	.95	<.2	3	.24	<.5	<.05
APR 29	.222	232	208	5	27.1	1.21	<.2	3	.29	<.5	<.05
MAY 02	.199	266	782	6	29.2	1.27	<.2	3	.30	<.5	<1
MAY 06	.161	229	213	5	23.5	1.02	<.2	3	.25	<.5	<1
MAY 09	.166	267	249	5	25.9	1.17	<.2	3	.27	<.5	<1
MAY 13	.165	288	270	6	27.9	1.20	<.2	3	.26	.5	<1
MAY 22	.131	334	322	6	30.9	1.31	<.2	3	.26	<.5	<1
MAY 30	.153	310	276	6	29.3	1.29	<.2	3	.25	.5	<1
JUN 10-19	.102	354	346	6	34.0	1.44	.7	3	.21	<.5	<.05
JUN 19			324								
JUN 27-JUL 05	.061	471		7	42.3	1.83	.7	4	.20	<.5	<.05
JUL 05			508								
JUL 11	.052	634	595	10	52.4	2.44	1.1	5	.21	<.5	<.05
JUL 18			681								
JUL 25	.198	551	367	9	44.8	2.24	1.1	4	.22	<.5	<.05
JUL 31	.195	560	682	9	44.5	2.22	.8	5	.22	<.5	<.05
AUG 13			482								
AUG 29			720								
AUG 29	.044	729		12	58.2	2.67	.4	6	.13	.6	<.05
SEP 11			720								
OCT	.093	580		10	45.9	2.10	.5	4	.14	.5	<.05
OCT 09			482								
OCT 31			561								
OCT(DUP)	.090	563		10	46.4	2.00	.6	5	.13	.5	<.05

Table 3.12 - SURFACE WATER - GROUP 3 PARAMETERS, SITE SW-02

Date (1985)	Cu mg/L	Fe mg/L	Fe2+ ug/L	K mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	P mg/L	Pb mg/L
JAN23 FEB 18-22(1)	.06	1690	-	46/52	154/156	16.9	.19/.25	42/44	.32	-	.56
FILTERED	.04	1590	1510	41	145	16.2	.18	40	.31	-	.56
UNFILT./FILT.	.09	1400	-	41	150	16.2	.14	40	.31	-	.51
TOTAL	.075	1540	-	41	147	16.1	.15	39	.31	-	.53
MAR 12	.04	1200	1090/1120	30	111	10.5	.13	30	.22	-	.37
MAR 18	.045	1400	1400	37	133	11.8	.18	36	.25	-	.52
MAR 25	.05/.06	1290	1200	34	122	10.6/10	.15	34	.26/.25	-	.46/.46
MAR 29	.06/.06	880	840	24	84	7/72	.1	23	.21/.23	-	.35/.42
APR 03	.091	936	895	23	96.8	7.57	<.2	22	.24	.5	<.05
APR 15			670								
APR 18			433								
APR 22	.058	269	280	9	33.1	2.47	<.2	8	.14	<.5	<1
APR 25			223								
APR 26	.012	-	195	1	-	.07[2]	<.2	1	<.05	<.5	<.05
APR 29	.072	153	149	7	23.5	1.63	<.2	6	.11	<.5	<.05
MAY 02	.064	172	447	7	24.5	1.73	<.2	6	.13	<.5	<1
MAY 06	.067	167	145	8	26.3	1.82	<.2	6	.13	<.5	<1
MAY 09	.067	180	146	8	25.8	1.89	<.2	6	.14	<.5	<1
MAY 13	.077	212	168	9	32.3	2.29	<.2	7	.15	<.5	<1
MAY 22	.078	272	222	11	39.8	2.93	<.2	9	.17	<.5	<1
MAY 30	.074	339	291	12	44.1	3.31	<.2	10	.16	<.5	<1
JUN 10-19	.077	555	335/670	17	71.4	5.05	1.0	14	.15	<.5	<.05
JUN 27-JUL 05	.057	1160	1040	31	123	9.78	2.2	26	.14	<.5	<.05
JUL 05			1230								
JUL 11	.054	1380	1310	35	139	11.2	2.2	31	.13	<.5	<.05
JUL 18			1390								
JUL 25	.060	1180	789	28	124	9.88	2.7	27	.13	<.5	<.05
JUL 31	.056	1140	1370	27	121	9.64	1.4	26	.12	<.5	<.05
AUG 13			1170								
AUG 29			1450								
AUG 29	.055	1540		38	162	12.6	1.0	33	.06	.9	<.05
SEP 11			1470								
OCT	.066	1540		38	160	12.1	.2	33	.05	1.0	<.05
OCT 09			1300								
OCT 31			1470								
OCT(DUP)	.067	1510		38	149	12.0	.8	33	.06	.9	<.05

Notes

1) See Table 3.37 for description of terminology

2) Values appear in error but were verified by laboratory

Table 3.13 - SURFACE WATER - GROUP 3 PARAMETERS, SITE SW-03

Date (1985)	Cu mg/L	Fe mg/L	Fe2+ ug/L	K mg/L	Mg mg/L	Mn mg/L	Mo mg/L	Na mg/L	Ni mg/L	P mg/L	Pb mg/L
JAN 23	.05	93/87	-	3.4/3.8	18/17.4	1.21	.02/.03	4.4/5.2	.10/.11		.12/.11
FEB 18-22[1]											
FILTERED	.08	148	<14	5	28	1.81	.03	6.4	.15	-	.17
MAR 12	.075/.08	146/137	56/15	4.8	26/24	1.7/1.52	.03/.03	6.1	.15/.14	-	.18/.19
MAR 18	.065	140	15	4.8	26	1.54	.035	5.7	.13	-	.19
MAR 21	.065	124	10	4.6	22	1.40	.02	5.5	0.1	-	.13
MAR 21 FIL	.77	89	-	5.1	25	1.37/1.44	.02	6.5	.13/.14	-	.18/.16
MAR 25	.065	133	21	4.6	23	1.44	.03	5.6	.12	-	.15
MAR 25 FIL	.14	88	-	4.8	24	1.42	.02	6.2	.13	-	.13
MAR 29	.055	116	15	4.3	19.6	1.27	.02	5.2	.12	-	.15
MAR 29 FIL	.10	75	-	4.5	21	1.25	.02	5.5	.11	-	.13
APR 03	.059	110	185	4	17.9	1.06	<.2	4	.10	<.5	<.05
APR 03 FL	.057	110		4	17.7	1.08	<.2	4	.10	<.5	<.05
APR 15	.048	110	70	4	17.1	.93	<.2	4	.10	<.5	<1
APR 18	.033	72.8	22	3	12.1	.64	<.2	2	.07	<.5	<1
APR 23	.020	30.0	28	2	4.66	.27	<.2	1	<.05	<.5	<.05
APR 24	.012	.96[2]	49[2]	1	.88[2]	.06[2]	<.2	1	<.05	<.5	<.05
APR 25	<.008	1.20[2]	6[2]	<1	.96[2]	.06[2]	<.2	<1	<.05	<.5	<.05
APR 26	.073	183	<9	6	27.6	1.97	<.2	6	.13	<.5	<.05
APR 29	.011	12.7	6	1	2.28	.14	<.2	1	<.05	<.5	<.05
APR 29 FL	.011	12.6	23	1	2.29	.14	<.2	<1	<.05	<.5	<.05
MAY 02[4]			11								
MAY 02A[3]	<.008	14.8	56	2	3.01	.18	<.2	<1	<.05	<.5	<1
MAY 06[4]			8								
MAY 06A[3]	.016	14.8	18	1	3.47	.22	<.2	1	<.05	<.5	<1
MAY 09[4]			5								
MAY 09A[3]	.016	19.2	22	2	4.55	.28	<.2	2	<.05	<.5	<1
MAY 13[4]			5								
MAY 13A[3]	.023	23.4	11	2	6.13	.38	<.2	2	<.05	<.5	<1
MAY 22[4]			84								
MAY 22A[3]	.030	28.3	111	2	8.67	.54	<.2	2	.06	<.5	<1
MAY 30[4]			4								
MAY 30A[3]	.031	32.0	11	3	10.1	.62	<.2	3	.06	<.5	<1
JUN 10[4]			7								
JUN 10A[3]			11								
JUN 19[4]			4								
JUN 19A[3]			4								
JUN 10-19	.038	48.1		4	14.4	.90	.2	3	.08	<.5	<.05
JUN 27-JUL 05	.040	30.6	7	4	13.7	.89	<.2	3	.08	<.5	<.05
JUL 05			16								
JUL 11	.037	22.0	16	3	11.9	.82	<.2	3	.10	<.5	<.05
JUL 18			10								
JUL 25	.034	24.1	11	4	11.8	.82	.2	3	.08	<.5	<.05
JUL 31	.029	24.2	10	3	12.0	.83	<.2	3	.08	<.5	<.05
AUG 13			7								
AUG 29	.051	42.2	72	4	20.2	1.40	<.2	4	.12	<.5	<.05
SEPT 11			14								
OCT	.053	79.5		4	23.1	1.67	<.2	5	.12	<.5	<.05
OCT 09			7								
OCT 31			6								
OCT(DUP)	.052	76.5		4	21.6	1.63	<.2	4	.12	<.5	<.05

Note:
1) See Table 3.37 for description of terminology
2) Values appear in error but were verified by laboratory
3) Alternative sampling location (upstream of barrier)
4) Analysis for sample from weir during period barrier was in place

TABLE 3.14 - SURFACE WATER - GROUP 4 PARAMETERS, SITE SW-01

Date (1985)	Se ug/L	Si mg/L	Sr mg/L	Th mg/L	Ti mg/L	V mg/L	Zn mg/L	Zr mg/L	LAB. COND. uS/cm	LAB. TDS mg/L
FEB 18-22	<4	18	.42	-	.22	.04	.20	-	3350	3900
MAR 12	<4	16	.28	-	.17	.02	.32	-	-	-
MAR 18	<4	21	.37	-	.20	.03	.18	-		
MAR 21	<1	21	.31	-	.20	.03	.24/.25	-		
MAR 25	<1	19	.29	-	.19	.03	.25/.22	-		
MAR 29	<1	14	.13	-	.10	.01	.17	-		
APR 03	<1	22.5	.290	.27	.036	<.005	.15	.14		
APR 18		13.5	.108	.19	.014	.017	.10	.06		
APR 22		14.7	.112	.19	.017	.010	.10	.06		
APR 25	<1	20.0	.181	.39	.029	<.005	.15	.11		
APR 26	<1	21.7	.210	.46	.034	.007	.15	.12	3380	1810
APR 29	<1	26.1	.263	.55	.043	<.005	.19	.16	4100	2500
MAY 02		26.9	.251	.40	.044	.026	.22	.16		
MAY 06		22.6	.207	.39	.041	.031	.19	.14		
MAY 09		21.9	.249	.34	.042	.030	.19	.14		
MAY 13		25.9	.249	.33	.044	.027	.18	.15		
MAY 22		24.8	.272	.23	.042	.025	.17	.15		
MAY 30		26.0	.268	.38	.045	.033	.18	.15		
JUN 10-19		26.6	.294	.44	.037	.049	.13	.11		
JUN 27-JUL05		27.7	.337	.35	.037	.064	.13	.12		
JUL 11		26.7	.394	.39	.043	.063	.14	.14		
JUL 25		23.4	.333	.89	.060	.064	.15	.13		
JUL 31		24.2	.330	.91	.064	.067	.15	.14		
AUG 29		24.0	.404	.13	.009	.008	.13	.12		
OCT		25.0	.347	.30	.009	<.005	.13	.09		
OCT(DUP)		24.6	.340	.26	.007	.014	.11	.10		

Table 3.15 : SURFACE WATER - GROUP 4 PARAMETERS, SITE SW-02

Date (1985)	Se ug/L	Si mg/L	Sr mg/L	Th mg/L	Ti mg/L	V mg/L	Zn mg/L	Zr mg/L	LAB. COND. uS/cm	LAB. TDS mg/L
JAN 23	<4	17/18	.08/.09	-	.26/.27	.06	.16	-	5500	7200/7100
FEB 18-22										
FILTERED (1)	<4	14	.78/.77	-	.28	.06	.18		5400	6600
UNFIL./FIL. (1)	-	16	.82	-	.29	.04	.25		5700	-
TOTAL (1)	-	17	.76	-	.29	.05	.17		-	-
MAR 12	<4	14	.60	-	.24	.04	.13		-	-
MAR 18	<4	15/15	.71	-	.27	.05	.12		-	-
MAR 25	<1	14	.65	-	.26	.04	.15/.17		-	-
MAR 29	<1	15	.45	-	.21	.03	.16/.19		-	-
APR 03	<1	19.9	.564	.34	.051	<.005	.13	.21	-	-
APR 22		11.7	.184	.19	.020	.030	.11	.08	-	-
APR 25										1660
APR 25 FIL									2330	
APR 26	<1	2.02	.014	.15	<.005	.013	<.05	<.05		
APR 29	<1	8.98	.150	.31	.018	.008	.07	.07	2550	1180
MAY 02		9.85	.141	.18	.019	.018	.09	.07		
MAY 06		10.1	.148	.24	.022	.023	.07	.08		
MAY 09		10.6	.155	.26	.026	.034	.08	.08		
MAY 13		12.4	.189	.29	.028	.028	.09	.10		
MAY 22		14.0	.226	.29	.030	.028	.09	.12		
MAY 30		15.9	.251	.18	.030	.024	.11	.12		
JUN 10-19		20.8	.371	.47	.045	.085	.10	.14		
JUN 27-JUL 05		21.7	.614	.40	.059	.123	.11	.19		
JUL 11		21.2	.693	.41	.064	.123	.11	.22		
JUL 25		19.3	.601	.43	.051	.128	.09	.19		
JUL 31		18.8	.591	.40	.050	.118	.09	.19		
AUG 29		20.9	.718	.17	.027	<.005	.09	.21		
OCT		21.0	.734	.18	.034	<.005	.13	.21		
OCT(DUP)		21.4	.719	.14	.032	<.005	.13	.22		

Notes:

1) See Table 3.37 for description of terminology

Table 3.16 : SURFACE WATER - GROUP 4 PARAMETERS, SITE SW-03

Date (1985)	Se ug/L	Si mg/L	Sr mg/L	Th mg/L	Ti mg/L	V mg/L	Zn mg/L	Zr mg/L	LAB. LAB. COND. uS/cm	LAB. LAB. TDS mg/L
JAN 23	<4	7.4	.09/.08		.06	<.01/.01	.06/.05	-	1380	560
FEB 18-22[1]										
FILTERED	<4	7.5	.12	-	.095	.01	.09	-	5600	-
UNFIL./FIL	<4	17.0	.76/.81	-	.30	.05	.23	-	-	-
TOTAL	<4	17.0	.79/.76	-	.26	.05/.06	.16/.20	-	-	-
MAR 12	<4	8.7/8.7	.12/.11	-	.11	.01	.07/[illegible]	-	-	-
MAR 18	<4	9.2	.12	-	.09	.01	.07	-	-	-
MAR 21	<1	8.5/8.7	.10	-	.09	<.01	.08	-	-	-
MAR 21 FIL	-	-	.12	-	-	<.01	1.29/1.35	-	-	-
MAR 25	<1	8.7	.11	-	.1	.01	.085	-	-	-
MAR 25 FIL	-	-	.11	-	-	<.01	.22	-	-	-
MAR 29	<1	7.8	0.1	-	.08	.01	.09	-	-	-
MAR 29 FIL	-	-	.10	-	-	<.01	.22	-	-	-
APR 03	<1	6.62	.081	.29	.026	.015	<.05	<.05		
APR 03 FIL	<1	6.61	.081	.23	.026	.012	<.05	<.05		
APR 15 FIL		6.63	.073	.18	.024	.015	.06	<.05		
APR 18 FIL		5.16	.056	.10	.014	.012	<.05	<.05		
APR 23	<1	2.93	.033	.12	.010	<.005	<.05	<.05	694	314
APR 24	<1	1.88	.014	.11	<.005	.010	<.05	<.05	75	40
APR 25	<1	2.05	.014	.08	<.005	<.005	<.05	<.05		
APR 26	<1	10.3	.176	.22	.019	<.005	.11	.07	119	70
APR 29A	<1	1.80	.018	.09	<.005	.008	<.05	<.05	363	154
APR 29A FIL	<1	1.87	.018	.07	<.005	.008	<.05	<.05	287	150
MAY 02A		2.08	.016	.05	<.005	<.005	<.05	<.05		
MAY 06A		2.24	.024	<.05	<.005	<.005	<.05	<.05		
MAY 09A		2.62	.027	.08	<.005	.005	<.05	<.05		
MAY 13A		3.11	.034	.20	<.005	.015	<.05	<.05		
MAY 22A		3.80	.044	.17	<.005	.019	<.05	<.05		
MAY 30A		4.08	.050	.13	.006	.014	<.05	<.05		
JUN 10-19A		5.10	.062	.26	.014	.029	<.05	<.05		
JUN 27-JUL05		7.47	.069	.21	.010	.018	.07	<.05		
JUL 11		9.47	.072	.14	.005	.010	.11	<.05		
JUL 25		8.47	.071	.18	.007	.019	.06	<.05		
JUL 31		8.46	.072	.12	<.005	.015	.06	<.05		
AUG 29		9.40	.098	.17	<.005	<.005	.07	<.05		
OCT		8.71	.106	.22	<.005	<.005	.06	<.05		
OCT(DUP)		8.65	.103	.21	<.005	<.005	.06	<.05		

NOTE
1) See Table 3.37 for description of terminology
2) "A" is alternative sampling location (upstream of barrier)

Table 3.17: SURFACE WATER - GROUP 5 PARAMETERS, SITE SW-01

Date (1985)	TKN mg/L-N	TOT.P ug/L	F- mg/L	Cl- mg/L	NO2- mg/L	PO4-3 mg/L	Br⁻ mg/L	NO_3^- mg/L	SO4= mg/L	
									LAB.	LAB.
FEB 22	4.5	150	2.5/4	4.2/5.3	10/48	<4/ <4	-	<21	2500/3300/35	
MAR 12	17.3	100	0.7	1.8	<1	<100	-	-	800	
MAR 18	10.4		1.9	5.1	9	<2	-	<2	2100	
MAR 21	36	100	0.7	5.1	5	<.4	-	<1	1880	
MAR 25	100	150	1.4/1.2	3.3/3.6	6	<1/ <1	-	<.5	810	
MAR 29	10	250	0.80	2.1	1	<2	-	<1	820	
APR 03			.94		<.02	<.1	<.1	<1	1480	
APR 18	.69	10	.29		<.02	<.1	<.1	<1	571	
APR 22			.28		<.02	<.1	<.1	<1	598	
APR 26	1.60	16	.71	1.26	<.02	<.1	<.1	<1	1120	
APR 29	1.90	11	.98	2.49	<.02	<.1	<.1	<1	1350	
MAY 02	2.74	27	.71		<.02	<.1	<.1	<1	1550	
MAY 06			.33		<.02	<.1	<.1	<1	1280	
MAY 09			.65		<.02	<.1	<.1	<1	1480	
MAY 13	2.40	27	.74		<.02	<.1	<.1	<1	1560	
MAY 22			1.26		<.02	<.1	<.1	<1	1630	
MAY 30	2.46	24	1.14		<.02	<.1	<.1	<1	1540	
JUN 10-19			.670		<.2	<1	<.5	<.50	1760	
JUN 27-JUL05			.900		<.2	<1	<.5	<.50	2030	
JUL 11	3.17	117	1.15		<.2	<1	<.5	<.50	2280	
JUL 25	3.32	93	.900		<.2	<1	<.5	1.00	2030	
JUL 31	3.32	69	.900		<.2	<1	<.5	.50	2050	
AUG 29			3.22	5.60	<.02	<.1	<5	<5	2070	
OCT			2.20	4.00	<.02	<.1	<5	<5	1770	
OCT(DUP)										

Table 3.18 - SURFACE WATER - GROUP 5 PARAMETER, SITE SW-02

Date (1985)	TKN mg/L-N	TOT.P ug/L	F- mg/L	Cl- mg/L	NO2- mg/L	PO4-3 mg/L	Br⁻ mg/L	NO_3^- mg/L	SO4= mg/L
JAN 23	12.6	100/200	2.6	26	<0.1	<2	-	<30	3100/4000
FEB 12-22	-	-	1	26	<5	<20	-	<20	4800
MAR 12	17.2	100	1.3	7.5	<1	<100	-	-	310
MAR 18	16.3/21.9	250/400	3.2	26	20	<4	-	<4	3900
MAR 25		200	2.8/2.6	20	12	<1	-	<1	3400
MAR 29		100	2.0	14.9	6	<2	-	<1	2400
APR 03			1.65		<.02	<.1	<.1	<2	2910
APR 22			.52	4.43	<.02	<.1	<.1	<1	972
APR 25	1.60	7							
APR 25 FIL			.43	5.08	<.02	<.1	<.1	<1	937
APR 26	1.50	9							
APR 29 UN	1.30	9	.56	3.66	<.02	<.1	<.1	<1	709
MAY 02	1.38	24	.36		<.02	<.1	<.1	<1	789
MAY 06			.51		<.02	<.1	<.1	<1	816
MAY 09			.22		<.02	<.1	<.1	<1	894
MAY 13	1.60	17	.31		<.02	<.1	<.1	<1	998
MAY 22			.83		<.02	<.1	<.1	<1	1190
MAY 30	2.59	20	1.30		<.02	<.1	<.1	<1	1370
JUN 10-19			1.20		<.2	<1	<.5	<.50	2130
JUN 27-JUL 05			1.51		<.2	<1	<.5	<.50	3600
JUL 11	5.19	93	1.56		<.2	<1	<.5	<.50	4020
JUL 25	6.36	85	1.39		<.2	<1	<.5	<.50	3520
JUL 31	6.95	85	1.41		<.2	<1	<.5	<.50	3520
AUG 29			4.08	20.8	<.02	<.1	<5	<5	3720
OCT			4.08	20.1	<.02	<.1	<5	<5	3720
OCT(DUP)									

Table 3.19: SURFACE WATER - GROUP 5 PARAMETERS, SITE SW-03

Date (1985)	TKN mg/L-N	TOT.P ug/L	F- mg/L	Cl- mg/L	NO2- mg/L	PO4-3 mg/L	Br⁻ mg/L	NO₃⁻ mg/L	SO4= mg/L
JAN 23	1.10/1.56	150	0.4	2.7/3.2	0.1	0.2	-	<.2	570
MAR 12	1.02/1.37	200	0.2	6.7	<1	<100	-	-	780
MAR 18	2.1	200	0.5	4.2	5	<4	-	<4	800
MAR 21	6.9	150	0.5	4.2	2	<1	-	<.5	750
MAR 25	6.9	100	0.4	3.6	2	<1	-	<.5	690
MAR 29	4.8	100	0.5	4.0	<1	<2	-	<1	660
APR 03			.21		<.02	<.1	<.1	<1	512
APR 03 FIL			.21		<.02	<.1	<.1	<1	512
APR 23	.50	11	.10	.61	<.02	<.1	<.1	<.20	173
APR 24			.04	.12	<.02	<.1	<.1	.90	21.6
APR 26	.30	9	.02	.19	<.02	<.1	<.1	.45	31.5
APR 29A	.30	3	.05	.37	<.02	<.1	<.1	1.16	84.3
APR 29A FIL	.30	5	.06	.36	<.02	<.1	<.1	1.10	85.2
MAY 02A			.08		<.02	<.1	<.1	<.2	116
MAY 06A			.09		<.02	<.1	<.1	<.2	134
MAY 09A			.11		<.02	<.1	<.1	<.2	173
MAY 13A			.15		<.02	<.1	<.1	<1	201
MAY 22A			.16		<.02	<.1	<.1	<1	266
MAY 30A			.22		<.02	<.1	<.1	<1	305
JUN 10-19			.127		<.02	<.1	<.05	.05	408
JUN 27-JUL 05			.124		<.02	<.1	<.05	.10	366
JUL 11	.24	14	.128		<.02	<.1	<.05	<.05	323
JUL 25	.46	37	.113		<.02	<.1	<.05	.05	315
JUL 31	.37	14	.113		<.02	<.1	<.05	.05	323
AUG 29			1.02	2.32	<.02	<.1	<5	<5	470
OCT			1.02	3.00	<.02	<.1	<5	14	510
OCT(DUP)			.72	2.32	<.02	<.1	<5	7	530

NOTE

1) "A" is alternative sampling location (upstream of barrier)

Table 3.20: SURFACE WATER - GROUP 6 PARAMETERS, SITE SW-01

Date (1985)	U (ppm)	Th-230 (Bq/L)	Ra-226 (Bq/L)	Pb-210 (Bq/L)	Po-210 (Bq/L)	Th-232 (Bq/L)	Ra-228 (Bq/L)	Th-228 (Bq/L)
Feb 25	0.205	5.59	0.68	0.33	0.34	0.71	1.0	0.89
Mar 12	0.300	6.17	0.72	1.89	0.24	0.80	0.9	0.34
Mar 18	0.21	3.41	0.52	0.14	0.43	0.27	<0.5	0.29
Mar 21	0.200	4.60	0.64	1.73	3.13	0.152	<4(1)	0.73
Mar 25	0.240	5.09	0.41	0.83	0.73	0.122	<4(1)	0.092
Mar 29	0.260	6.85	0.57	4.09	0.67	0.430	-	0.377
Apr 03	0.280	7.9	0.74	3.9	1.0	-	<0.4	-
Apr 15-18	0.190	5.4	0.65	3.6	0.70	0.60	0.60	0.70
Apr 22	0.157	5.5	0.64	2.8	0.49	0.90	<0.4	-
Apr 26	0.260	9.8	0.58	2.5	0.54	1.10	0.82	-
Apr 27/ May 2	0.353	11.0	0.50	2.6	0.82	1.6		-
May 02	-	-	-	-	-	-	0.63	-
May 6/9	0.327	13.0	0.65	3.4	0.34	1.6	1.6	1.0
May 21/28	0.298	9.0	0.70	5.3	0.22	1.5	0.67	-
Jun 10	0.250	7.7	0.84	3.2	1.1	0.93	2.0	1.1
Jun 27	0.210	5.2	0.79	<1.0	0.92	0.47	<1.0	0.65
Jul 05	0.180	4.1	0.89	<1	0.68	1.1	<1	1.4
Jul 25/31	0.500	17.7	1.0	2.8	1.5	4.9	<1	2.0
Jul 25/31(1)	0.490	25.0	1.8	2.8	1.2	3.1	1.9	2.0
Aug(2)	.310	10.5	1.10	5.4		1.12		0.53
Sep(2)	.165		0.90					
Oct(2)	.210	8.9	0.68	2.0	0.45	0.62		0.28

Notes:

1) Blind Duplicate
2) Initial values reported were 2.8 and 2.0, but were later judged to be detection limit of <4
3) High Ra-223 present

Table 3.21: SURFACE WATER - GROUP 6 PARAMETERS, SITE SW-02

Date (1985)	U (ppm)	Th-230 (Bq/L)	Ra-226 (Bq/L)	Pb-210 (Bq/L)	Po-210 (Bq/L)	Th-232 (Bq/L)	Ra-228 (Bq/L)	Th-228 (Bq/L)
Feb 05	0.14	5.63	0.77	0.22	0.67	<0.5	<0.5	1.09
Feb 25	0.120	5.05	0.25	0.11	0.23	0.65	<0.5	(1)
Mar 12	0.110	4.70	0.21	0.51	0.12	0.76	<0.5	0.55
Mar 18	0.125	4.22	0.20	0.33	0.18	0.21	<4(2)	0.051
Mar 25	0.109	4.02	0.27	0.48	0.08	0.184	-	(1)
Mar 29	0.125	4.67	0.18	<.1	0.16	0.224	<0.5	0.012
Apr 03	.193	7.2	0.35	1.8	0.31	1.0	<0.4	0.40
Apr 15-18	.138	4.0	0.50	1.2	0.95	-	0.45	-
Apr 22	.108	3.0	0.40	1.1	0.16	0.32	<0.4	0.25
Apr 25/26	.093	3.6	1.2	1.8	0.29	0.40	<0.4	0.50
Apr 27/May2	.130	4.4	0.75	1.5	0.34	0.60	-	1.3
Apr 29	-	-	-	-	-	-	<0.4	-
May 6/9	.123	4.6	0.80	2.4	0.30	1.1	1.2	0.70
May 21/28	0.140	8.0	0.65	2.7	0.13	1.1	<0.4	1.4
Jun 10	0.190	6.4	0.65	1.2	0.51	0.67	1.3	0.66
Jun 27	0.140	2.8	0.73	<1	0.54	0.42	<1	1.1
Jul 5	0.175	2.2	0.84	<1	0.44	0.33	<1	1.1
Jul 25/31(3)	.077	3.1	0.56	<1	0.17	0.45	<1	0.70
Jul 25/31(3)	.125	3.4	0.74	<1	0.25	0.41	<1	0.83
Aug(4)	.074	1.7	0.70	1.8		0.22		0.12
Sep(4)	.067		0.70	<1				
Oct(4)	.090	2.2	0.49		<.01	0.21		0.24

Notes:

1) Th-227 present
2) Initial value reported was 1.3 but subsequently judged to be detection limit.
3) Blind Duplicate
4) High Ra-223

Table 3.22: SURFACE WATER - GROUP 6 PARAMETERS, SITE SW-03

Date (1985)	U (ppm)	Th-230 (Bq/L)	Ra-226 (Bq/L)	Pb-210 (Bq/L)	Po-210 (Bq/L)	Th-232 (Bq/L)	Ra-228 (Bq/L)	Th-228 (Bq/L)
Feb 05	0.09	8.84	<0.5	0.99	0.93	<0.5	3.3	1.29
Feb 25	0.200	14.1	0.53	0.11	0.46	1.78	<0.5	1.16
Mar 12	0.180	14.1	0.35	1.49	0.37	1.56	0.7	0.99
Mar 18	0.175	10.7	0.38	-	-	0.61	-	0.53
Mar 21	-	-	0.60	-	0.51	0.77	-	0.65
Apr 03	0.120	6.1	0.60	3.1	0.69	0.70	<0.4	0.72
Apr 15-18 UNF	0.109	6.0	0.45	2.4	0.73	0.60	0.53	1.3
Apr 15-18 FI[1]	0.104	6.0	0.50	1.7	0.48	0.75	0.48	0.79
Apr 18 UNF	0.062	3.2	0.70	2.3	0.58	0.40	-	0.42
Apr 18 FI[1]	0.063	3.4	0.40	1.9	0.42	0.25	-	1.3
Apr 22	0.028	1.5	1.0	2.9	0.75	0.10	-	0.30
Apr 23/26	0.010	0.55	0.40	1.1	0.53	<0.05	-	0.17
Apr 29A[2]	-	-	-	-	-	-	<0.4	-
May 6/9A[2]	0.020	1.3	0.55	1.6	0.23	0.20	0.75	0.20
May 21A[2]	-	-	-	-	-	-	0.50	-
Jun 10A[2]	0.110	4.3	0.70	1.5	0.60	0.36	<1	0.44
Jun 27	0.065	3.4	0.68	<1	0.58	0.32	<1	0.33
Jul 05	0.034	1.2	0.88	<1	0.37	0.18	<1	0.16
Jul 27/31(3)	.033	0.88	0.64	<1	0.24	0.12	<1	0.13
Jul 27/31(3)	.034	1.0	0.82	<1	0.27	0.13	<1	0.11
Aug (4)	0.088	3.6	0.86	2.7		0.30		0.30
Sep (4)	0.088		0.77					
Oct (4)	0.125	4.1	0.46	<1	0.31	0.38		0.28

Notes:

1) Filtered sample (0.45 um)
2) A=alternate site sample (pond)
3) Blind Duplicate
4) High Ra-223

TABLE 3.23 SURFACE WATER - SURFACE SAMPLES DURING SPRING MELT

Location	Cond. (uS/cm)	Anal.(1) Temp. (°C)	pH	F^- (mg/L)	Cl^- (mg/L)	NO_2^- (mg/L)	PO_4^{3-} (mg/L)	Br^- (mg/L)	NO_3^- (mg/L)	SO_4^{2-} (mg/L)	U (ppm)	Ra-226 (Bq/L)
SW-04	1150	18	5.35	0.05	0.24	<0.02	<0.1	<0.1	<1.00	1.97	<0.0005	<0.05
SW-05	2700	18	4.2	0.05	0.35	<0.02	<0.1	<0.1	<0.20	129	0.002	1.10
SW-06	230	0	5.65	0.16	1.38	<0.02	<0.1	<0.1	0.44	0.39	0.002	0.05
SW-07	6000	18	3.80	0.24	1.28	<0.02	<0.1	<0.1	<1.00	297	0.028	1.0
SW-08	9500	18	3.60	0.31	1.51	<0.02	<0.1	<0.1	<1.00	484	0.040	4.5
SW-09	7400	18	3.45	0.29	0.93	<0.02	<0.1	<0.1	<1.00	349	0.047	2.1
SW-10	8600	18	3.35	0.32	1.47	<0.02	<0.1	<0.1	<1.00	414	0.007	2.0
SW-11	4400	18	3.55	0.25	1.13	<0.02	<0.1	<0.1	<1.00	325	0.031	2.3

Note

1) Temperature at time of analysis

TABLE 3.24 SURFACE WATER - INTERLABORATORY COMPARISON OF CATIONS FOR 15 APRIL SAMPLE (UNITS: mg/L)

	SW-01		SW-02		SW-03		
	Barringer[1]	BEAK[2]	Barringer[1]	BEAK[2]	Barringer Analysis[2,3]	Barringer Analysis[1,3]	BEAK[2]
Ag	<.05	0.02/< 0.01	.005	< 0.01	0.005	<.005	0.03
Al	22.6	19.9	15.5	12.5	7.79	8.44	7.5
B	.019	0.11	.131	0.34	< 0.004	.008	0.04
Ba	.007	< 0.01	<.005	< 0.01	0.009	.009	0.01
Be	.0014	< 0.01	.0014	< 0.01	0.0005	.0008	< 0.01
Ca	153	131	223	210	60.6	63.9	52
Cd	.03	0.05/0.05	.07	0.17	< 0.01	.01	0.03
Co	.16	0.15/0.16	.18	0.22	0.11	.15	0.11
Cr	<.01	0.04/0.04	<.01	0.07	0.03	.02	0.04
Cu	.130	0.12/0.12	.068	0.06	0.048	.051	0.05
Fe	182	152	700	590	110	108	94
K	4	4.2	19	20	4	5	4.4
Mg	19.9	19.7	83.3	80	17.7	18.3	16.9
Mn	.92	0.83/0.82	6.16	5.5	0.93	1.05	0.87
Mo	<.2	0.06	<.2	0.11	< 0.2	<.2	0.03
Na	2	4.5	18	20	4	4	5.2
Ni	.14	0.16/0.16	.11	0.19	0.10	.10	0.08
Pb	<.05	0.24/0.24	<.05	0.32	< 1	<.05	0.16
Si	17.5	14	17.8	14	6.63	7.31	5.5
Sr	.171	0.16	.430	0.42	0.073	.079	0.08
Ti	.020	0.13	.039	0.21/0.22	0.024	.025	0.10
V	.017	0.02	.005	0.03	0.015	.006	0.01
Zn	.13	0.12/0.12	<.05	0.13	0.06	<.05	0.04

Notes

1 Samples analyzed December 1985.
2 Sample analyzed May-June, 1985.
3 Note Barringer analysis in May-June, 1985 and in December 1985 were made from same bottle

TABLE 3.25 SURFACE WATER - INTERLABORATORY COMPARISON OF CATIONS FOR 29 APRIL SAMPLE (UNITS: mg/L)

	SW-01		SW-02		SW-03	
	Barringer	BEAK	Barringer	BEAK	Barringer	BEAK
Ag	< 0.005	< 0.01	< 0.005	< 0.01	< 0.005	< 0.01/< 0.01
Al	38.6	32/32	10.1	8.7	1.15	0.67/0.66
B	0.603	0.2/0.1	0.391	0.10/0.09	0.025	0.03
Ba	0.007	0.01/0.01	0.012	0.01	0.008	< 0.01/< 0.01
Be	0.0028	< 0.01/< 0.01	0.0011		< 0.0005	
Ca	250	210/240	102	82	15.4	12.3/13.6
Cd	0.02	0.06	< 0.01	0.04	< 0.01	< 0.01
Co	0.34	0.24	0.20	0.01	0.06	< 0.01
Cr	0.01	0.07	< 0.01	0.03	< 0.01	0.08
Cu	0.222	0.20	0.072	0.06	0.011	0.01
Fe	232	196	153	130	12.7	11.6
K	5	5.4/5.2	7	6.7	1	0.54/0.52
Mg	27.1	28/28	23.5	23	2.38	2.1/2.1
Mn	1.21	1.09	1.63	1.42	0.14	0.12
Mo	< 0.2	0.05/0.08	< 0.2	0.03	< 0.2	< 0.01/< 0.01
Na	6	6.0/7.0	6	6.0	1	1.0/1.2
Ni	0.11	0.26	0.11	0.10	< 0.05	< 0.01
Pb	< 0.05	0.28	< 0.05	0.21	< 0.05	0.02
Si	26.1	21/20	8.98	7.2	1.80	1.5/1.5
Sr	0.263	0.24/0.25	0.150	0.13	0.018	0.01/0.02
Ti	0.043	0.19	0.018	0.10	< 0.005	0.04
V	< 0.005	0.02/0.03	0.008	0.01	0.008	< 0.01/< 0.01
Zn	0.19	0.18	0.07	0.07	< 0.05	< 0.01

TABLE 3.26 SURFACE WATER - INTERLABORATORY COMPARISON OF NON-RADIONUCLIDE PARAMETERS FOR 19 JULY SAMPLE (UNITS: mg/L)

	SW-01		SW-02		SW-03	
	Barringer[1]	BEAK[1]	Barringer	BEAK	Barringer	BEAK
Ag	< 0.005	< 0.01	< 0.005	0.02	< 0.005	< 0.01
Al	26.8	17.6	17.7	13.2	9.40	8.2
As	< 1	8	< 1	8	-	< 1
B	0.011	0.28	< 0.004	0.61/0.59	< 0.004	0.02
Ba	0.005	0.01	0.008	0.02	0.030	0.03
Be	0.0015	< 0.01	0.0013	< 0.01	< 0.0005	< 0.01
Ca	401	410	407	430	50.1	46
Cd	< 0.01	0.10	< 0.01	0.21	< 0.01	< 0.005
Co	0.23	0.26	0.29	0.40	0.10	0.08
Cr	0.27	0.06	0.57	0.07	0.02	< 0.01
Cu	0.052	0.045	0.054	0.040	0.037	0.030
Fe	634	600	1,380	1,280	22	18.9
K	10	11.4	35	36	3	2.9
Mg	52.4	51	139	141	11.9	11.2
Mn	2.44	2.3	11.2	10.6	0.82	0.72
Mo	1.1	0.10	2.2	0.15	< 0.2	0.10
Na	5	10.2	31	37	3	2.9
Ni	0.21	0.26	0.13	0.29	0.10	0.09
Pb	< 0.05	0.51	< 0.05	0.67	< 0.05	0.02
Si	26.7	24	21.2	18	9.47	8.7
Sr	0.394	0.41	0.693	0.69	0.072	0.08
Ti	0.043	0.23	0.064	0.28	0.005	0.04
V	0.063	0.03	0.123	0.05	0.010	< 0.01
Zn	0.14	0.14	0.11	0.14	0.11	0.10
TP	0.117	< 0.02(2)	0.093	< 0.02(2)	0.14	0.008
Kjel N	3.17	3.5	5.19	7.2	0.24	0.80
Nitrate N		2.3(3)		3.6(3)		0.8/0.9[3]
F- (mg/L)	1.15	1.9	1.56	3.1	0.128	0.3
Cl-	2.16	4.9	10.7	22/22	0.60	1.4/1.6
NO_2^-	< 0.2	1.2	< 0.2	0.6	< 0.02	0.3
PO_4^{3-}	< 1	< 1	< 1	< 1	< 0.1	< 1
NO_3^-	< 0.5	< 1	< 0.5	< 1	< 0.05	< 0.1
SO_4^{2-}	2,280	1,700	4,020	4,500	323	310

Notes

1) Labelled as 11 July to Barringer, 19 July to BEAK
2) Low recovery on spikes; sample interference
3) Measured by BEAK by wet methods. The values are high because of iron interference and hence are rejected (ie. they are not true values)

TABLE 3.27 SURFACE WATER - INTERLABORATORY COMPARISON OF TIC (UNITS: mg/L)

	SW-01		SW-02		SW-03	
	BEAK	Check	BEAK	Check	BEAK	Check
08/01/85	6.5	11.46	L 0.5	2.53	1.0	2.94
08/13/85	10.0	9.75	2.0	2.48	2.0	2.83
08/29/85	15.5	7.24	3.0	2.39	4.0	6.38
09/11/85	9.5	8.12	2.0	2.92	1.5	2.56

TABLE 3.28 SURFACE WATER - NON-RADIONUCLIDE PARAMETER ANALYSIS OF BLIND REPLICATE BY BARRINGER FOR JULY 25 AND 31 COMPOSITE SAMPLE (UNITS mg/L UNLESS NOTED)

	SW-01		SW-02		SW-03	
	Analysis 1	Analysis 2	Analysis 1	Analysis 2	Analysis 1	Analysis 2
Ag	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Al	31.7	31.0	16.9	16.6	7.66	7.65
As	2	2	1	1	< 1	< 1
B	0.213	0.200	0.300	0.205	< 0.004	< 0.004
Ba	0.011	0.012	0.008	0.008	0.025	0.025
Be	0.0020	0.0020	0.0013	0.0011	0.0006	0.0007
Ca	310	316	362	352	46.4	46.5
Cd	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Co	0.31	0.33	0.29	0.26	0.15	0.10
Cr	0.32	0.31	0.57	0.54	0.02	0.02
Cu	0.198	0.195	0.060	0.056	0.034	0.029
Fe	551	560	1,180	1,140	24.1	24.2
K	9	9	28	27	4	3
Mg	44.8	44.5	124	121	11.8	12.0
Mn	2.24	2.22	9.88	9.64	0.82	0.83
Mo	1.1	0.8	2.7	1.4	0.2	< 0.2
Na	4	5	27	26	3	5
Ni	0.22	0.22	0.13	0.12	0.08	0.08
P	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Pb	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Si	23.4	24.2	19.3	18.8	8.47	8.46
Sr	0.333	0.330	0.601	0.591	0.071	0.072
Th	0.89	0.91	0.43	0.40	0.18	0.12
Ti	0.060	0.064	0.051	0.050	0.007	< 0.005
V	0.064	0.067	0.128	0.118	0.019	0.015
Zn	0.15	0.15	0.09	0.09	0.06	0.06
Zr	0.13	0.14	0.19	0.19	< 0.05	< 0.05
TKN	3.32	3.32	6.36	6.95	0.46	0.37
TP (ug/L)	93	69	85	85	37	14
F-	0.900	0.900	1.39	1.41	0.113	0.113
Cl-	2.08	2.08	9.42	9.46	0.61	0.61
NO_2^-	< 0.2	< 0.2	< 0.2	< 0.2	< 0.02	< 0.02
PO_4^{3-}	< 1	< 1	< 1	< 1	< 0.1	< 0.1
Br-	< 0.5	< 0.5	< 0.5	< 0.5	< 0.05	< 0.05
NO_3^-	1.00	0.50	< 0.5	< 0.5	0.05	0.05
SO_4^{2-}	2,030	2,050	3,520	3,520	315	323

TABLE 3.29 SURFACE WATER - NON-RADIONUCLIDE PARAMETER ANALYSIS OF BLIND REPLICATE BY BARRINGER FOR OCTOBER SAMPLE (UNITS: mg/L)

	SW-01		SW-02		SW-03	
	Analysis 1	Analysis 2	Analysis 1	Analysis 2	Analysis 1	Analysis 2
Ag	< .005	< .005	< .005	< .005	< .005	< .005
Al	23.3	22.6	18.7	18.4	11.1	10.6
B	< .004	< .004	< .004	< .004	< .004	<.004
Ba	.007	.005	.006	.010	.014	.014
Be	.0019	.0017	.0021	.0023	.0009	.0008
Ca	296	290	387	386	77.1	72.2
Cd	.02	.03	.04	.05	< .01	< .01
Co	.17	.16	.21	.23	.20	.18
Cr	.06	.06	< .01	< .01	.06	.06
Cu	.093	.090	.066	.067	.053	.052
Fe	580	563	1540	1510	79.5	76.5
K	10	10	38	38	4	4
Mg	45.9	46.4	160	149	23.1	21.6
Mn	2.10	2.00	12.2	12.0	1.67	1.63
Mo	.5	.6	.2	.8	< .2	< .2
Na	4	5	33	33	5	4
Ni	.14	.13	.05	.06	.12	.12
Pb	< .05	< .05	< .05	< .05	< .05	< .05
Si	25.0	24.6	21.0	21.4	8.71	8.65
Sr	.347	.340	.743	.719	.106	.103
Th	.30	.39	.18	.59	.22	.40
Ti	.009	.007	.034	.032	< .005	< .005
V	< .005	.014	< .005	< .005	< .005	< .005
Zn	.13	.11	.13	.13	.06	.06
Zr	.09	.10	.21	.22	< .06	< .06

TABLE 3.30 SURFACE WATER - INTERLABORATORY COMPARISON OF RADIONUCLIDE ANALYSES FOR MARCH SAMPLES (UNITS: Bq/L UNLESS NOTED)

Date/Laboratory	U (ppm)	Th-230 (Bq/L)	Ra-226 (Bq/L)	Th-232 (Bq/L)	Ra-228 (Bq/L)	Th-228 (Bq/L)
SW-01 25 March						
Chemex	0.210	4.1	2.1	0.9	0.60	1.0
SRC	0.125	5.5	1.7	0.45	0.80	0.45
Monenco	0.24	5.09	0.41	0.122	2.0[1]	0.092
SW-01 29 March						
Chemex	0.240	4.2	1.6	1.2	0.4	1.2
SRC	0.200	7.5	1.2	0.50	0.55	0.50
Monenco	0.260	6.85	0.57	0.43	[3]	0.377
SW-02 25 March						
Chemex	0.090	3.9	1.8	1.2	0.5	1.0
SRC	0.115	4.0	1.1	0.60	0.30	0.60
Monenco	0.109	4.02	0.27	0.184	[3]	[2]

NOTE

1 Sample originally had a value reported but subsequently the lab decided that it was a detection limit value (i.e. < 2)

2 Not measurable due to presence of Th-227.

3 Not analyzed

TABLE 3.31 SURFACE WATER - INTERLABORATORY COMPARISON OF RADIONUCLIDE ANALYSES FOR JUNE-JULY SAMPLES (UNITS: Bq/L)

		Th-230	Ra-226	Th-232	Th-228
SW-01	Monenco	4.1	0.89	1.1	1.4
	SRC	3.5	2.5	1.7	1.7
	Chemex	4.9	1.72	0.64	0.64
SW-02	Monenco	2.2	0.84	0.33	1.1
	SRC	1.5	3.0	1.9	2.0
	Chemex	2.8	2.1	0.43	0.43
SW-03	Monenco	1.2	0.88	0.18	0.16
	SRC	1.2	1.1	0.25	0.25
	Chemex	2.0	1.0	0.20	0.20

TABLE 3.32 SURFACE WATER - INTERLABORATORY COMPARISON OF RADIONUCLIDE ANALYSIS OF LEAD-210 FOR OCTOBER SAMPLE (UNITS: Bq/L)

		Pb-210
SW-01	Monenco	2
	Chemex	1.43
SW-02	Monenco	< 1
	Chemex	0.38
SW-03	Monenco	< 1
	Chemex	0.91

TABLE 3.33 SURFACE WATER - RADIONUCLIDE ANALYSIS OF BLIND REPLICATE JULY SAMPLE BY MONENCO

Date	U (ppm)	Th-230 (Bq/L)	Ra-226 (Bq/L)	Pb-210 (Bq/L)	Po-210 (Bq/L)	Th-232 (Bq/L)	Ra-228 (Bq/L)	Th-228 (Bq/L)
SW-01								
25 July	0.500	17.7	1.0	2.8	1.5	4.9	< 1	2.0
31 July	0.490	25.0	1.8	2.8	1.2	3.1	1.9	2.0
SW-02								
25 July	0.077	3.1	0.56	< 1	0.17	0.45	< 1	0.70
31 July	0.125	3.4	0.74	< 1	0.25	0.41	< 1	0.83
SW-03								
27 July	0.033	0.88	0.64	< 1	0.24	0.12	< 1	0.13
31 July	0.034	1.0	0.82	< 1	0.27	0.13	< 1	0.11

TABLE 3.34 SURFACE WATER - RADIONUCLIDE ANALYSIS OF BLIND REPLICATE OCTOBER SAMPLE BY MONENCO (UNITS: Bq/L UNLESS NOTED OTHERWISE)

Station	U (ppm)	Th-230	Ra-226	Pb-210	Th-232	Th-228
SW-01	0.210	8.9	0.68	2	0.62	0.28
	0.215	8.5	0.64	< 1	0.63	0.32
SW-02	0.0895	2.2	0.49	< 1	0.21	0.24
	0.160	2.0	0.68	< 1	0.21	0.14
SW-03	0.123	4.1	0.46	< 1	0.38	0.28
	0.125	3.6	0.54	< 1	0.31	0.30

TABLE 3.35 SURFACE WATER - INTERLABORATORY COMPARISON OF NON-RADIONUCLIDE PARAMETERS FOR GUNNAR TAILING AREA FIELD PROGRAM (JUNE) (UNITS: mg/L, UNLESS OTHERWISE NOTED)

	Barringer W-6 June	BEAK 6 June	BEAK 7 June	Barringer W-12 June	BEAK 12 June
Ag	< 0.005			< 0.005	
Al	0.02	0.32		< 0.01	0.24
As	-	< 1		-	< 1
B	0.289	0.36/0.28		0.213	0.30
Ba	0.015	0.02		0.011	0.02
Be	< 0.0005	< 0.01		< 0.0005	< 0.01
Ca	188	194		213	200
Cd	< 0.01	0.010		< 0.01	< 0.005
Co	< 0.05	0.02		< 0.05	0.02
Cr	0.01	0.02		0.01	0.02
Cu	0.010	0.010		< 0.008	0.010
Fe	0.26	0.60		0.64	0.72
K	3	3.9		2	4.2
Mg	163	180		168	183
Mn	3.25	3.3		6.07	6.1
Mo	< 0.2	0.03		< 0.2	0.03
Na	48	49		49	51
Ni	< 0.05	0.02		0.05	0.01
P	< 0.5			< 0.5	
Pb	< 0.05	0.10		< 0.05	0.09
Si	6.03	6.5		6.44	6.6
Sr	0.412	0.48		0.433	0.49
Th	0.06			< 0.05	
Ti	0.011	0.15		0.016	0.17
V	0.124	0.01		0.132	0.01
Zn	< 0.05	0.020		< 0.05	0.020
Zr	< 0.05			< 0.05	
pH		7.4	7.6		
Conductivity (uS/cm)		1,900	1,950		
Alkalinity		27	25		
Dissolved Solids		1,870	1,880		
Kjeldahl N		1.17	-		
Nitrate-N		0.06/0.05	-		
TOC		27	-		
F-		0.4	0.4		
Cl-		60	74		
NO_3^-		< 2	< 5		
PO_4^{3-}		< 0.1	< 5		
NO_3^-		< 0.2	< 0.5		
SO_4^{3-}		1,090	1,040		

TABLE 3.36 SURFACE WATER - INTERLABORATORY COMPARISON OF RADIONUCLIDE PARAMETERS FOR GUNNAR TAILING AREA FIELD PROGRAM (MARCH) (Bq/L, UNLESS OTHERWISE NOTED)

Date/Lab #	U (ppm)	Th-230	Ra-226	Th-232	Ra-228	Th-228
SW-C1 March						
SRC	0.019	0.12	2.0	< 0.1	0.1	< 0.1
Monenco	0.021	0.101	1.91	< 0.005	< 4[1]	0.022
SW-C2 March						
SRC	0.021	0.13	1.8	< 0.1	0.35	< 0.1
Monenco	0.021	0.156	2.04	< 0.005	< 4[1]	0.26
SW-C3 March						
SRC	0.020	< 0.2	2.0	< 0.2	0.4	< 0.2
Monenco	0.024	0.130	2.16	< 0.005	< 4[1]	< 0.005

NOTE

1) Originally Reported Value, subsequently judged to be detection limit of < 4 Bq/L because the samples were analyzed by Monenco personnel in the middle of experimental solutions with levels of 100 Bq/L.

TABLE 3.37 SURFACE WATER - STUDY OF FIELD AND LABORATORY FILTRATION

		SW01			SW02							SW03		
		SW01-1	SW01-2	SW01-3	SW02-1	SW02-2	SW02-3	SW02-4A	SW02-4B	SW02-5A	SW02-5B	SW03-1	SW03-2	SW03-3
Parameter														
pH		3.8	1.5		3.2	1.3						2.9		
Alkalinity	mg/L													
Acidity	mg/L	1590/1560			2640							500		
Conductivity	uS/cm	3350			5400			5700		5600		1800		
Total Dissolved Solids	mg/L	3900			6600							1200		
TIC	mg/L	1.0		9.0	1.5							1.5		
TOC	mg/L			0.05			10.0							4.0
Nitrite	mg/L			0.6			0.03							0.02
Nitrate	mg/L			4.2			0.5							2.3
Ammonia-N	mg/L			4.5			6.7							1.58
Kjeldahl-N	mg/L			0.15			7.3/6.6							1.23
Phosphate-P	mg/L						0.10							0.10
Ion Chromatography	mg/L													
Fluoride		2.5	4.0		2.5/2.4	4.5		1		2		0.5	0.8	
Chloride		4.2	5.3		31	27		26		37/28		4.9	5.7	
Nitrite		10	48		<5	36		<5		<10		<0.2	38/28	
O-Phosphate		<4	<4		<4	<4		<20		<20		<1	<5	
Nitrate		<2			<30			<20		<20		<1		
Sulphate		2500	3300/3100		4600/5100	4000		4800		4900		790	250	
Iron(2+)	mg/L			780			1510							<14
DCPScan	mg/L													
Beryllium			<0.01			<.01/<.01		<0.01	<0.01	<.01/<.01	<.01/<.01		<0.01	
Molybdenum			0.12			0.18/0.18		0.14	0.15	0.15/0.17	0.15/0.18		0.03	
Calcium			310			390/380		400	370	360/390	390/360		91	
Vanadium			0.04			0.06/0.06		0.04	0.05	0.05/0.05	0.05/0.06		0.01	
Aluminum			20			13.7/13.7		14.8	14.3	14.6/16.0	14.6/15.9		13.2	
Magnesium			53			145/145		150	147	148/148	148/146		28	
Barium			0.01			0.01/0.01		0.08	0.01	0.05/0.05	0.01/<0.01		0.01	
Potassium			15.9			41/41		41	41	41/40	41/41		5.0	
Strontium			0.42			0.78/0.77		0.82	0.76	0.76/0.81	0.79/0.76		0.12	
Sodium			10.4			40.40		40	39	40/40	40/40		6.4	
Zinc			0.20			0.18		0.25	0.17	0.23/0.23	0.16/0.20		0.090	
Cadmium			0.23			0.43		0.40	0.40	0.39/0.50	0.42/0.65		0.035	
Manganese			3.6			16.2		16.2	16.1	16.1/12.4	15.9/12.7		1.81	
Cobalt			0.28			0.44		0.44	0.44	0.46/0.45	0.45/0.49		0.18	
Copper			0.110			0.040		0.090	0.075	.060/.065	.050/.03		0.080	
Silver			0.015			0.020		0.02	0.02	0.02	0.01		<0.01	
Iron			800			1590		1400	1540	1430/1550	1520/1610		148	
Lead			0.42			0.56		0.51	0.53	0.57/0.57	0.56/1.09		0.17	
Chromium			0.05			0.07		0.06	0.07	0.07/0.08	0.07/0.19		0.04	
Nickel			0.27			0.31		0.31	0.31	0.33/0.33	0.31/0.31		0.15	
Silica (SiO_2)			38			30		35/35	36	36	35		16	
Boron			0.50/0.55			0.90		0.68	0.66	0.66	0.65		0.20	
Titanium			0.22			0.28		0.29	0.29	0.30	0.26		0.095	
Arsenic	mg/L		4 / 3			1/2		2	6	2	4		2	
Selenium	mg/L		<4			<4		<4	<4	<4	<4		<4	

NOTE
SW01-1 Field filtered, unpreserved.
SW01-2 Field filtered and preserved with HNO3.
SW01-3 Field filtered and preserved with H2SO4.
SW02-1 & SW03-1 Field filtered and unpreserved.
SW02-2 & SW03-2 Field filtered and preserved with HNO3.
SW02-3 & SW03-3 Field filtered and preserved with H2SO4.
SW02-4A & SW03-5A Not filtered in field. Filtered in lab and analyzed.
SW02-4B & SW03-5B Not filtered in field. Acidified in lab to dissolve precipitation and analyzed.

TABLE 3.38 SURFACE WATER - ANALYSIS OF FILTER PAPER (CONCENTRATIONS IN ug/FILTER PAPER)[1]

Element	Concentration	Element	Concentration
Ag	< .05	Mo	< 2
Al	64.9	Na	< 10
Be	.008	Ni	< .5
Ca	35.9	P	6
Cd	.1	Pb	6.5
Co	< .5	Sr	.45
Cr	< .1	Th	1.1
Cu	.95	Ti	4.86
Fe	3360	V	.35
K	520	Zn	1.2
Mg	15.4	Zr	< .5
Mn	1.0		

NOTE

1) 1 Litre of water filtered

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PONDING ON TAILINGS AS A RESULT OF THE TEMPORARY DAM

PONDING ON TAILINGS AS A RESULT OF THE TEMPORARY DAM

STATION SW-02 UNDER CONSTRUCTION

STATION SW-01

TEMPORARY DAM UPSTREAM OF SW-03

STATION SW-03 SHOWING 90° V-NOTCH

Number/
Numéro

4

CONTRACT SERIAL NO: OSQ84-00196

CONTRACTOR: GOLDER ASSOCIATES

REQUISITION NO: 23241-4-1680

LACNOR FIELD STUDY
ELLIOT LAKE, ONTARIO

APPENDIX 4
BIOLOGY

Prepared for

The National Uranium Tailings Program

By

Golder Associates

Beak Consultants SENES Consultants

Cumming - Cockburn & Associates

March 1986

50 pp

APPENDIX 4 - BIOLOGY

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APPENDIX 4: BIOLOGY

4.1 Introduction

4.1.1 Scope and Objectives

In December 1984, Golder Associates, SENES Consultants Limited, Beak Consultants Limited and Cumming-Cockburn and Associates Limited were awarded a contract by the National Uranium Tailings Program to carry out the field study at the Lacnor uranium tailings area in Elliot Lake, Ontario. The intent of the project, as set out in the terms of reference, was:

> "The design and operation of a sampling program, incorporating chemical, physical and biological data that will be used to characterize the Lacnor tailings and environs, and which will provide raw data for the study of processes involving tailings constituents and their pathways."

The field study, therefore, required the sampling of tailings solids, subtailings soil and rock, the surrounding soil and rock, tailings porewater, surface water, the measurement of surface water runoff, the gathering of atmospheric data and a biological assessment of the site.

This appendix (Appendix 4 to the main overview report) provides details of the relevant background data and of the 1985 field program. The information on the field program includes procedures and sampling sites, laboratory methods, quality assurance/quality control (QA/QC) program and presentation of data.

4.1.2 Appendix Outline

This appendix is organized into the following sections:

4.2: **Overview of Biological Component** provides a brief description of the biological data collection component of this study, and the major tasks carried out during the 1985 field program.

4.3: **Historical Data** provides a brief summary of the currently available regional historical biological data. Unfortunately, very little site-specific historical data are available of direct relevance to the Lacnor site.

4.4: **Field Program** provides details on the field program, with specific reference to bacteria, vegetation, soils and wildlife.

Photographs from the field investigations are included at the end of the appendix.

4.1.3 Schedule of Events

During March and April 1985, five cores were collected during the geotechnical field program for bacterial analysis. Above-ground biomass samples were collected from major vegetation communities on the Lacnor tailings area during the week of 29 July to 01 August 1985. This late July and early August period corresponds to the period of peak biomass in central Ontario. The wildlife program was limited to analysis of flesh and molar samples from five beavers trapped in the Lacnor area by local trappers over the summer of 1985.

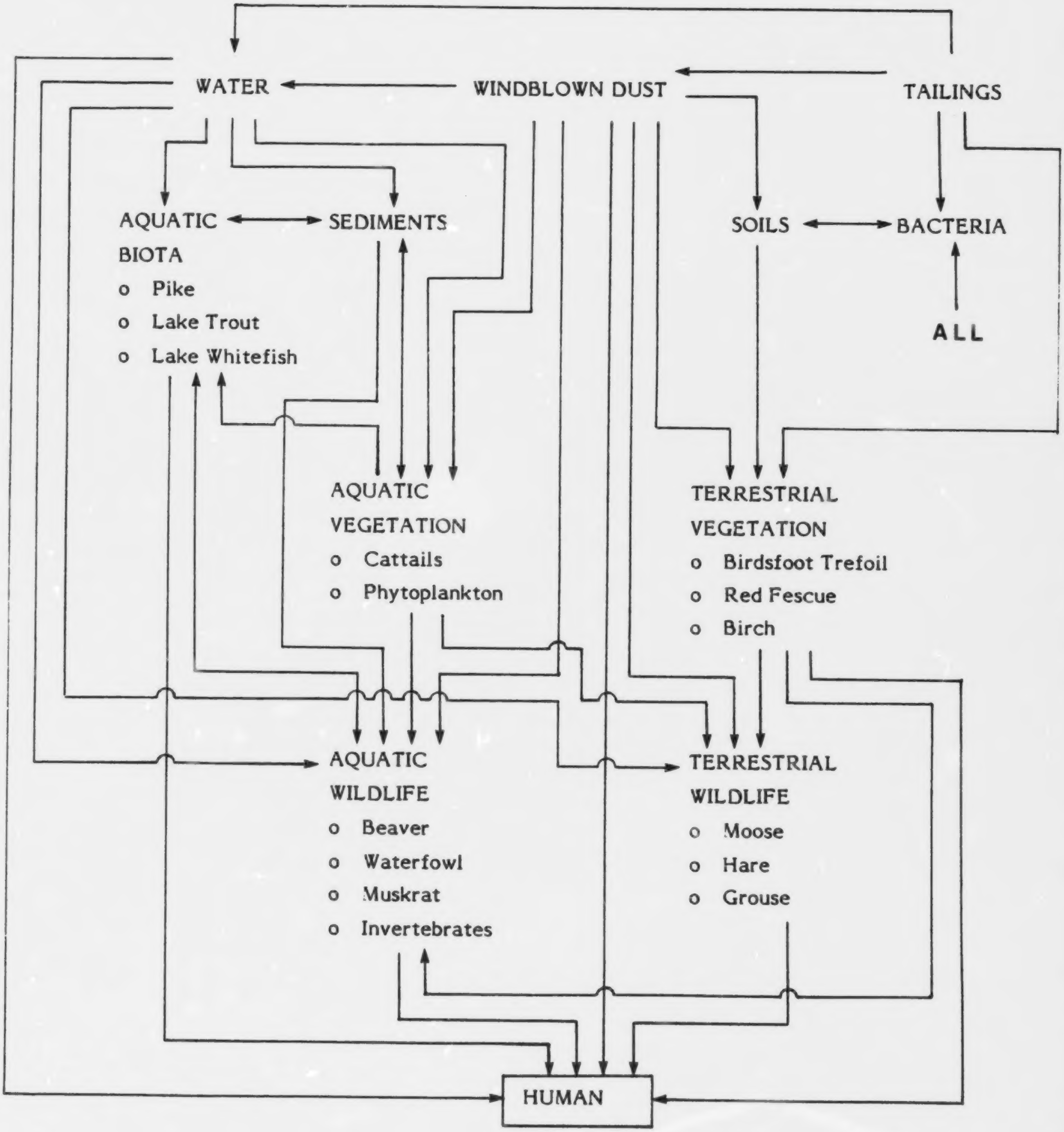
4.2 Overview of Biological Component

The primary objective of the biological data collection component of this study was to assemble information which could ultimately be used in computer modelling to predict the potential radionuclide or metal doses to humans through the consumption of fish, wildlife or vegetation which have been exposed to emissions or effluents from closed uranium tailings facilities. A simplified food chain for the Lacnor site is presented in Figure 4.1.

With this objective in mind, the major tasks of the biological study were:

- to identify the important food chain transfer pathways;
- to determine the distribution densities of key food chain species;
- to determine the probable consumption rates of these species through the food chain to humans; and
- to determine the radionuclide concentrations in these species.

FIGURE 4.1: SIMPLIFIED FOOD CHAIN BASED ON SPECIES FROM THE LACNOR AREA


WATER
WINDBLOWN DUST
TAILINGS
AQUATIC BIOTA
o Pike
o Lake Trout
o Lake Whitefish
SEDIMENTS
SOILS
BACTERIA
ALL
AQUATIC VEGETATION
o Cattails
o Phytoplankton
TERRESTRIAL VEGETATION
o Birdsfoot Trefoil
o Red Fescue
o Birch
AQUATIC WILDLIFE
o Beaver
o Waterfowl
o Muskrat
o Invertebrates
TERRESTRIAL WILDLIFE
o Moose
o Hare
o Grouse
HUMAN

Initially, the biological component of the study focused on three biological groups, collecting both existing background information and samples for laboratory analyses from each. However, the study of aquatic biota was omitted from the field program since the study of existing data indicated there are no aquatic animals which are primarily affected by the Lacnor tailings site alone. The parameters studied in the biological communities include:

Vegetation

- Community distribution and composition,
- Species abundance.
- Biomass,
- Radionuclide and metal concentrations in selected species living in the tailings area, and
- Consumption rates of dominant species by game animals (or humans).

Wildlife

- Distribution, abundance and seasonal movements,
- Types and rates of food consumption.
- Local population size and age structure,
- Concentrations of radionuclides and metals in edible portions of flesh, and
- Data on human harvest and consumption.

Aquatic Ecology

There are no site-specific data on aquatic animals for the Lacnor site. Drainage from the Lacnor tailings runs directly into the much larger Nordic tailings site via three small channels. Physical and chemical properties of these streams have not been conducive to the establishment of aquatic fauna. Field collection of aquatic animals was thus not attempted in the Lacnor drainage system. Regional data on contaminants in the Serpent River drainage have been collected.

Bacteria

Bacterial populations were sampled and characterized from cores taken from within the Lacnor tailings.

Field sampling in this study was designed to maximize the information provided relative to radionuclide and metal concentrations at critical stages in the food chain. Regional data availability is the opposite in that much information is found in the literature, but little of direct relevance to Lacnor. Regional data were thus screened to emphasize relevance to project objectives, data quality and relevance to the Lacnor tailings.

Data Collection

Two types of data were collected in this study, regional data from the many past studies of the Elliot Lake mining area, and site-specific data collected during the current study at the Lacnor tailings site. The data were evaluated to determine their suitability in meeting the study objectives. The parameters used to evaluate appropriateness of the data included:

- relevance to food chain modelling;
- proximity to the study site;
- adequate spatial and temporal distribution of samples;
- probability of interference from other tailings sites;
- documentation of sample collection, handling, preservation and analytical procedures;
- quality assurance/quality control programs; and
- adequacy of reporting.

The suitability of data for modelling purposes depends to a great extent on the specific modelling application. For example, a much larger body of data is required for input to a stochastic model since probability density functions must be defined for each model parameter. For deterministic models, mean parameter values can be input; however, confidence in the model prediction still depends on the expected range of variation for each parameter. The effects of such variation are usually investigated by means of a sensitivity analysis of the model.

The sensitivity analysis will identify parameters that have a significant effect on model predictions. For these parameters, it is important to accurately assess the range of environmental variation. In radionuclide dispersion models, for example, water column particulate adsorption coefficients and particle settling velocities are the major factors controlling human dose commitment downstream of uranium tailings sites (IEC BEAK, 1983). However, pH and moisture are important factors controlling radionuclide mobilization and release from the tailings.

Past monitoring has generally considered the Lacnor tailings to be a component of the much larger Nordic tailings area. For this reason, few regional data were pertinent to predictive modelling of the Lacnor tailings. Some emphasis was thus placed on the site-specific monitoring carried out as part of the present study. Regional studies also indicated the absence of a control site in the area that could be compared to Lacnor. With the cumulative effects of the many similar mines and tailings areas surrounding the Lacnor site, no appropriate, uncontaminated control was identified.

4.3 Historical Data

4.3.1 Data Available

Until recently, the only studies specific to the Lacnor area related to revegetation (Kalin, 1983, 1984; Davé et al., 1984). These are regional studies which include some values from the Lacnor site. A series of recent studies on mammals and vegetation have looked at radionuclides in small mammals and vegetation in the Lacnor and Nordic tailings area. These have included calculations of transfer coefficients (Cluthier et al., 1985, 1986, in press). At the time of writing, other papers have been submitted, but results are not available until they have been accepted (Clulow, pers. comm., 1986). The lack of detailed studies specific to the Lacnor tailings is a result of the relatively short life (about three years) and small area (approximately 24 ha) of this tailings site compared to others in the Elliot Lake area. The drainage from Lacnor tailings travels a relatively short distance before it enters the much larger Nordic tailings site. Thus, prior to entering a receiving stream where it could affect the biological cycle, effluents from the Lacnor site are mixed with much greater volumes from the Nordic site. Regional data are also masked through the presence of many larger tailings sites in the vicinity.

Regional historical data were collected for Elliot Lake drainage sub-basin and portions of the Serpent River drainage system. The Elliot Lake sub-basin has only two tailings sites draining into it, the small Lacnor site which operated from 1957 to 1960 producing 2.7 million tonnes or 24 ha of tailings, and the large Nordic site which operated from 1957 to 1968 producing 10.9 million tonnes or 107 ha of tailings. These data were then reviewed to determine relevance to modelling of impacts from the Lacnor tailings. Copies of the most significant references pertinent to this study are provided in the Lacnor Project Box File.

In presenting these data, it is assumed that the releases from the Lacnor tailings cannot be differentiated from those of the Nordic tailings since the two tailings systems are integrated and only separated by about 500 m. It is further assumed that once the Elliot Lake sub-basin drainage enters McCarthy Lake, influences of the many tailings sites draining into the Serpent River will totally mask any effects of the Lacnor/Nordic drainage and will no longer be discernible.

Even with the above assumptions, there are a number of problems in evaluating the regional data base. Initially, there is no way to determine how much of any contamination of biota in the Elliot Lake sub-basin can be assigned to the Lacnor rather than Nordic tailings. The Nordic site is about four times the size and is downstream from Lacnor. In reality, the Lacnor drainage has probably little impact outside of its immediate surroundings. Several potential sources of data would not release some of their information. These included the CANMET research group, university researchers, Serpent River Indian Band (who conducted a study on human consumption of biota), and Ministry of Environment. Those data which were released in most cases had no discussion of quality assurance/control methods. The majority of data available relate to operating mines. Few data are available for Lacnor (closed 1960) or Nordic (closed 1968) sites. Some of the radioactivity measurements are gross alpha or gross beta and not of specific radionuclides.

The historical, regional data are summarized by trophic levels as follows:

- Soils and bacteria,
- Vegetation (including agriculture, forestry and phytoplankton),
- Invertebrates,

- Fish, Amphibians and Reptiles,
- Birds and Mammals, and
- Human.

4.3.2 Soils and Bacteria

No relevant references were found on bacteria. Data on concentrations in soils and tailings follow.

McIlveen (1977)

- Soils in the Elliot Lake area near CANMET mine vents have Pb-210 activities of 110 to 1,100 mBq/g.

Kalin (1983)

- The range of soils concentrations of a number of metals are reported for soils in the Elliot Lake area and compared to literature values of soils in control areas.
- Other tables in this report compare metal concentrations from tailings in the Elliot Lake and Bancroft areas. Data are reported as averages or ranges with exact sites not identified.
- No conclusive correlation could be found between either radionuclide or metal levels in tailings and vegetation growing on them. All radionuclide concentration ratios plant/tailings were less than one, except for radium-226 which showed slight tendencies for bioconcentration.

Dave et al. (1984)

- Radionuclide activities are reported for tailings substrate and vegetation at several sites in the Elliot Lake area.
- Activities from the Lacnor site were reported as:

Activity (mBq/g dry weight±analytical precision)

Radionuclide	Substrate	Grasses	Birdsfoot Trefoil
Ra-226	5,032±222	425±26	259±19
Ra-223	1,554±111	30±4	15±4
Pb-210	3,515±185	85±26	107±26
Th-232	116±26	L 4	L 4
Th-230	555±74	L 4	L 4
Th-228	74±37	L 4	L 4

L = less than.

- All plant/tailings activity ratios were less than 1.
- Only Ra-226, Ra-223 and Pb-210 levels were detectable in vegetation at the Lacnor site (as well as other locations).
- No radionuclides were detected in control vegetation.

4.3.3 Vegetation Data

Ontario Environmental Assessment Board (1979)

- CANMET has committed to modelling radium vegetation - herbivore pathways. (Note: this study was not yet available).
- CANMET/Nordic area air quality (existing/predicted with expansion): suspended particulates 45/49 ug/m^3; dustfall 153/156 g/m^3; radon 15/16 mBq/L.

MacLaren (1977) (Volume 1)

- Great Lakes - St. Lawrence Region vegetation with low forest productivity.
- Using Dunlop as a control, there are significant declines in population and diversity of phytoplankton in lakes downstream from tailings outfalls.
- Provides species list of macrophytes in Serpent River system.

MacLaren (1978) (Volume 2)

- 60 ha of Nordic tailings successfully reseeded at this time. CANMET monitoring.

MacLaren (1978) (Volume 4)

- Produce grown in home gardens at 2 kg/m^2 yield would result in Ra-226 activities of 7.7 Bq/kg. Ingestion at 64 kg/a would result in 4.8×10^2 Bq/a.
- Similar calculations (not detailed in report) predict annual per person activity ingestion of Th-230 from local produce as 1.9×10^2 Bq/a.

McIlveen (1977)

- Pb-210 found elevated in most common colonizing trees on tailings, white birch. Two samples on Nordic tailings had Pb-210 activities of 240 and 520 mBq/g.

Kalin (1983)

- Cattails are the most common colonizers of wetlands and white birch or trembling aspen are the most common colonizers of dry uplands at tailings in the Elliot Lake area.
- Lists of plant species found on the Lacnor tailings and the mean concentrations of metals in tailings and soils from the Elliot Lake area are copied in Appendix 4.
- No conclusive correlations could be found between tailings and the vegetation growing on them for either metals or radionuclides measured.
- Radionuclide plant/tailings activity ratios were less than one for all but radium-226.

Kalin (1984)

- Cattails grow equally well on uranium tailings as at control sites. Species diversity is generally lower on the tailings, while both vegetative and sexual reproduction are stimulated by the harsher tailings environment.
- Trembling aspen and white birch generally attain the same height and diameter when grown on tailings as on control sites, but take a longer growth period to reach this size.

Davé et al. (1984)

- No correlation found between concentrations of radionuclides in vegetation and tailings grown on.
- Only Ra-226, Ra-223 and Pb-210 found in detectable levels on vegetation from tailings areas. No radionuclides were detectable in control vegetation. The detectable Ra-226 and Pb-210 levels were not felt to be significant in terms of bioaccumulation potential in higher trophic levels.
- Plant/tailings activity ratios were all less than one.

Ministry of Natural Resources
Espanola District (D. Corbett, pers. comm., 1985)

- Area has 76% productive forest (28% poplar, 17% white birch, 12% red pine, 9% black spruce, 10% hardwood).
- There are 91 farms in Spanish River Township totalling 11,557 ha. Average 180 d growing season. Oats, barley and beef are main production.

Ontario Water Resources Commission (1972)

- Little growth or use of local produce in area, so therefore not important pathway.

4.3.4 Invertebrates

Data were only found on aquatic invertebrates.

MacLaren (1977) (Volume 1)

- Zooplankton numbers and diversity significantly reduced downstream from tailings sites. This was blamed on pH not radioisotopes.
- Benthos diversity indices indicate pollution at Nordic seepage to Westner Lake (div = 1.3) and flow to Nordic Lake (div = 0.6). Elliot Lake is moderately polluted with div = 3.1 to 3.2.

- Clams are generally absent in these lakes. The reference indicates that this absence might be caused by an intolerance of sulphates and/or tendency of these filter-feeders to accumulate high levels of radionuclides.

4.3.5 Fish

MacLaren (1977) (Volume 1)

- Downstream from tailings sites, lake trout are in poor condition and have spawning failures. Walleye populations are reduced due to losses of spawning habitat on Serpent River.
- At and downstream from McCarthy Lake, some good fishing areas remain.
- The Serpent Harbour commercial fishery includes relatively stable harvests of walleye, pike, sturgeon, whitefish, but no longer lake trout (due to lamprey).

MacLaren (1978) (Volume 4)

- Estimated maximum dose to fish in Serpent River = 3.8×10^{-3} Gy/a.
- Elliot Lake sub-basin is generally not affected by tailings except Nordic and Westner Lakes, both of which have few to no fish.
- Serpent River fish have mean activities of 2.6 Bq/g (flesh) gross alpha.

MacLaren (1978) (Addendum 1)

- There is no correlation between fish flesh radiological values and lakes caught in; however, for two whole fish analyzed, much higher concentrations occurred than in flesh samples alone.
- Analyzed as dry weight and then multiplied by four to estimate concentration wet weight. No pre- and post-drying measurements to justify this.

D. Corbett, pers. comm. (1985) - Espanola MNR

- 30% of residents in area fish.
- At Whiskey Lake in 1966, 131 ice fishermen caught 136 trout and 10 pike in 16 days (0.38 trout/h).

Duckworth (1977)

	Lake			
	Whiskey	Pecors	McCarthy	Elliot
pH	low	low	5.7	control
TDS	high	high	low	control
Fish	-	poor	healthy	healthy

Blind River District

Ministry of Natural Resources Data

In 1984, they stocked 1,000 brook trout in May Lake and 2,000 brook trout in McCabe Lake.

Commercial Fish (1984)

District harvest included the following numbers of fish:

Carp:	511	Pilots:	924
Catfish:	115	Suckers:	409
Eels:	14	Sturgeon:	1,244
Lake Herring:	2,804	Sunfish:	288
Lake Trout:	1,595	Whitefish:	325,583
Ling:	159	Walleye:	15,271
Northern Pike:	5,169	Salmon:	703
Yellow Perch:	69,457		
TOTAL			116,370 fish

4.3.6 Reptiles and Amphibians

No data were found on these species relevant to the study area.

4.3.7 Birds and Mammals

Cluthier et al. (1985, 1986, in press)

A series of studies have been recently published, are in press, or have been submitted for publication, which include assessments of radionuclide and trace metal concentrations in vegetation, meadow voles and snowshoe hares from the Lacnor and Nordic tailings areas (Clulow, pers. comm., 1986). One of these (Cluthier et al., 1985) reported on radium-226, copper, nickel, iron, cobalt, zinc and lead levels in meadow voles living on mine tailings. A second publication (Cluthier et al., 1986) reported seasonal changes in skeletal radiation dose to voles ranging from 5×10^{-5} Gy/day in fall to 4×10^{-4} Gy/day in spring. This latter dose rate would result in a lifetime dose of 0.025 Gy which the authors conclude is below levels likely to cause cancer. A third study (Cluthier et al., in press a) reported radium-226 levels in vegetation on uranium tailings averaging 211 mBq as compared to less than 7 mBq in control areas. Seasonal levels reported for voles and the calculated transfer coefficients are:

Season	Ra-226 in Vole Skeletons (mBq)	Transfer Coefficient
Summer	1,506 ± 625	$(4.6 \pm 2.9) \times 10^{-2}$
Fall	703 ± 59	$(2.8 \pm 0.6) \times 10^{-2}$
Winter	6,083 ± 673	-
Spring	7,163 ± 1,077	-
Control	L 7.4	-

These transfer coefficients have been confirmed by laboratory studies not yet published. A fourth study (Cluthier et al., in press b) noted that the highest concentrations of radium-226 were found in feces of snowshoe hares from the Lacnor site (203 ± 85 mB/g) compared to Stanrock and Nordic or to control sites (3.7 mB/g).

MacLaren (1978) (Volume 4)

- Common species in area of tailings include moose, white-tailed deer, red fox, gulls, ravens, waterfowl. Others observed include common merganser, mallard, Canada goose, ruffed grouse, snowshoe hare, beaver, lynx, black bear, and small mammals.

MacLaren (1978) (Addendum I)

Measured wildlife radionuclide activities from Elliot Lake area:

	Pb-210 mBq dry	Ra-226 mBq dry
Deer	18.5	5.5
Moose	74	3.6

D. Corbett pers. comm. (1985)
Ministry of Natural Resources Espanola District

- o District 38 (see map in Appendix 4): mean moose density 1975-1977 = 16.8/km^2.
- o 1976 - 2,800 hunters shot 102 moose.
- o 1974 - 1,984 ducks shot (1.79/hunter).

Ministry of Natural Resources (1983; pers. comm., 1985)

- o Appendix 4 contains details on hunting and trapping for the district obtained both from Ministry files and Land Use Guidelines (MNR, 1983).

Ministry of Natural Resources (1980)

- o The Espanola District strategic land use plan includes data on trapping and hunting harvests for the district.

R. Maloney, pers. comm. (1986)
Atomic Energy Control Board

The AECB is currently completing a study of radionuclide concentrations in moose and moose browse in the Elliot Lake area to determine bioconcentration factors. Results were not available at the time this report was written.

4.3.8 Human

MacLaren (1978) (Volume 4)

- Air pathway: inhalation rate of 8,400 m^3/a results in inhaled activities of 0.1 Bq/a Th-230 and 1.1 Bq/a Ra-226. Estimate Pb-210 = 4 to 20 x Ra-226.
- Measurements of town water supply range 14 to 40 mBq/L Ra-226. Pb-210 levels around 560 mBq/L.
- Fish with activities of 2.6 mBq/g gross alpha eaten at a rate of 7.3 kg/a result in ingestion of 10 Bq/a Ra-226.
- Homegrown produce at 7.8 Bq/kg Ra-226 ingested at 64 kg/a results in 499 Bq/a Ra-226 ingestion. Similar calculations estimate Th-230 ingestion = 192 Bq/a.

MacLaren (1978) (Addendum 1)

- Hunter's eat average of 46 kg of game/family/a game. Assuming family of two eating equal amounts of deer (0.006 s/g dry Ra-226) and moose (0.003 s/g dry) is equal to 1 mBq/g wet weight Ra-226. The annual ingestion per person is 25.5 Bq/a Ra-226.
- Similar calculations for Pb-210 estimate dose at 278 Bq/a/person.
- Game was thus concluded to be the most significant human food exposure pathway.

Duckworth (1977)

- One resort and 13 cottages on Whiskey Lake.

Ontario Environmental Assessment Board (1979)

- Drinking water supplies for Serpent River Band and Elliot Lake town 1977-78 = 0.15 to 0.2 Bq/L.

Serpent River Indian Band (pers. comm., 1985)

- The Band planner has conducted a study of subsistence eating of local fish, game, trapped species, berries and other vegetation. This was not available either through the Band, through Indian and Northern Affairs, nor through the local medical health authority.

N. Bedi and P. Clifford (1980)

o Adult Anglers in Northeastern Region (x 1,000):

Age	16-24	25-34	35-44	45-54	55-64	65+	Unknown	Total
Number	15.4	39.4	28.9	22.2	13.0	5.9	5.5	130.3

o Anglers by District:

	Residents # (x 1,000)	x̄ Annual Effort (Angler Days)	Total Anglers including Non-residents (x 1,000)	x̄ Annual Effort (Angler Days)
Blind River	9.0	13.3	28.3	8
Espanola	5.7	21.1	52.3	8

o Catch by spp./District (caught/kept):

	Smallmouth Largemouth Bass	Pike	Panfish	Perch	Rock Bass	Smelt
Blind River	94/63	38/22	*	*	*	612/590
Espanola	203/124	90/61	698/411	536/391	134/9	*

Communities Within 80 km Elliot Lake

Elliot Lake	18,670[1]	Serpent River	388
Espanola	5,786[1]	Spragge	100[3]
Whitefish Falls	350[1]	Algoma Mills	100[3]
McGregor Bay	100[3]	Blind River	3,564[1]
Magawong Village	100[3]	Mississauga	380[2]

Kagawong	100[3]	Iron Bridge	814[1]
Gore Bay	779[1]	Sowerby	100[3]
Sheshagwaning	153[2]	Thessalon	1,575[1]
Meldrum Bay	100[3]	Thessalon I. Res.	104[2]
Webbwood	513[1]	Little Rapids	100[3]
McKerrow	100[3]	Dunns Valley	100[3]
Waltford	100[3]	White Lake	100[3]
Cutler	100[3]	Silverwater	100[3]
TOTAL			34,476

[1] Ontario Municipal Directory (1984) (1982 population).

[2] DIAND, 1983 Schedule of Indian bands (population 1981). (Note some Bands doubled population in one year?).

[3] Those for which no statistics were found were estimated as 100.

4.4 Detailed Biological Results

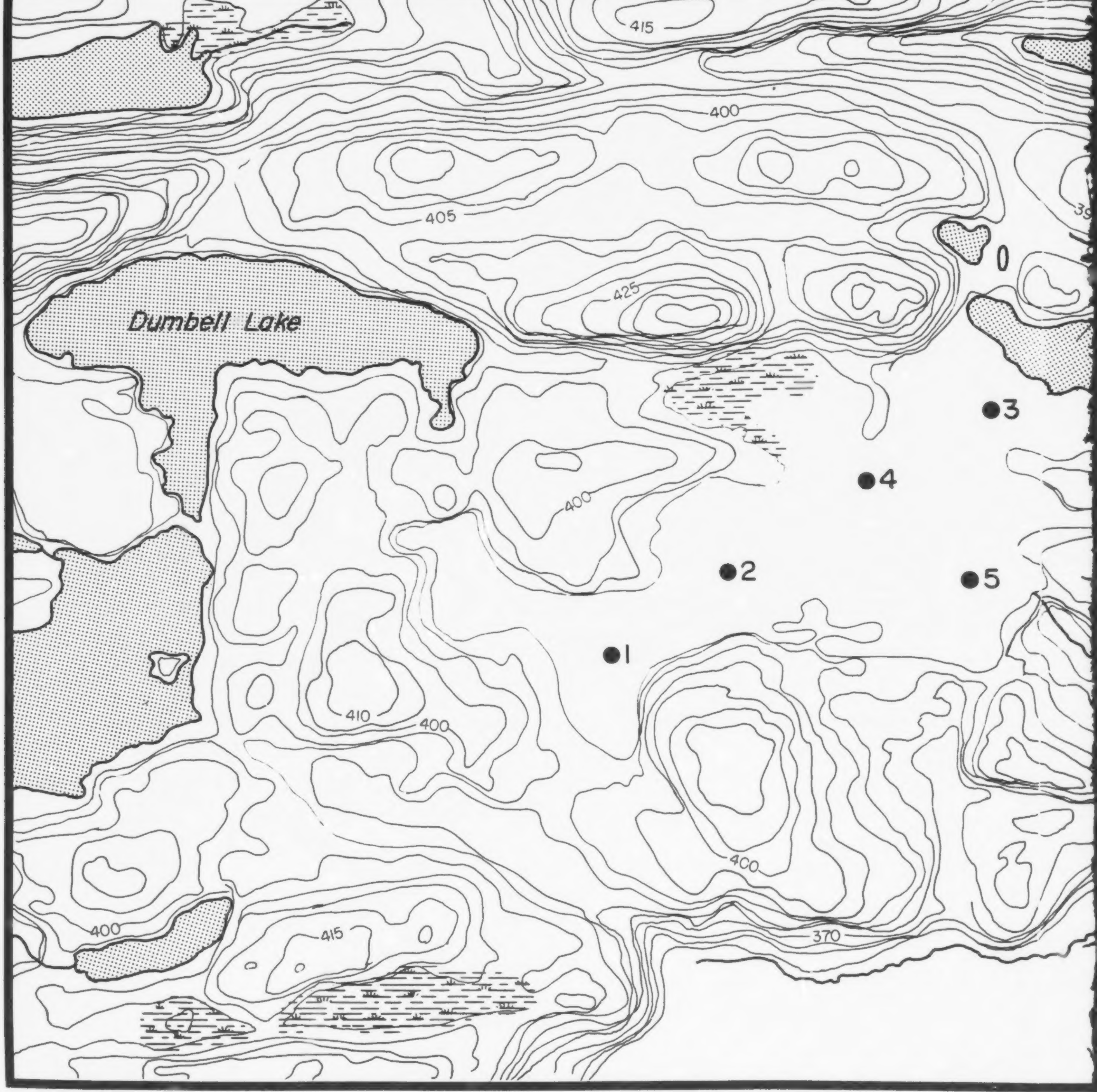
4.4.1 Bacteria

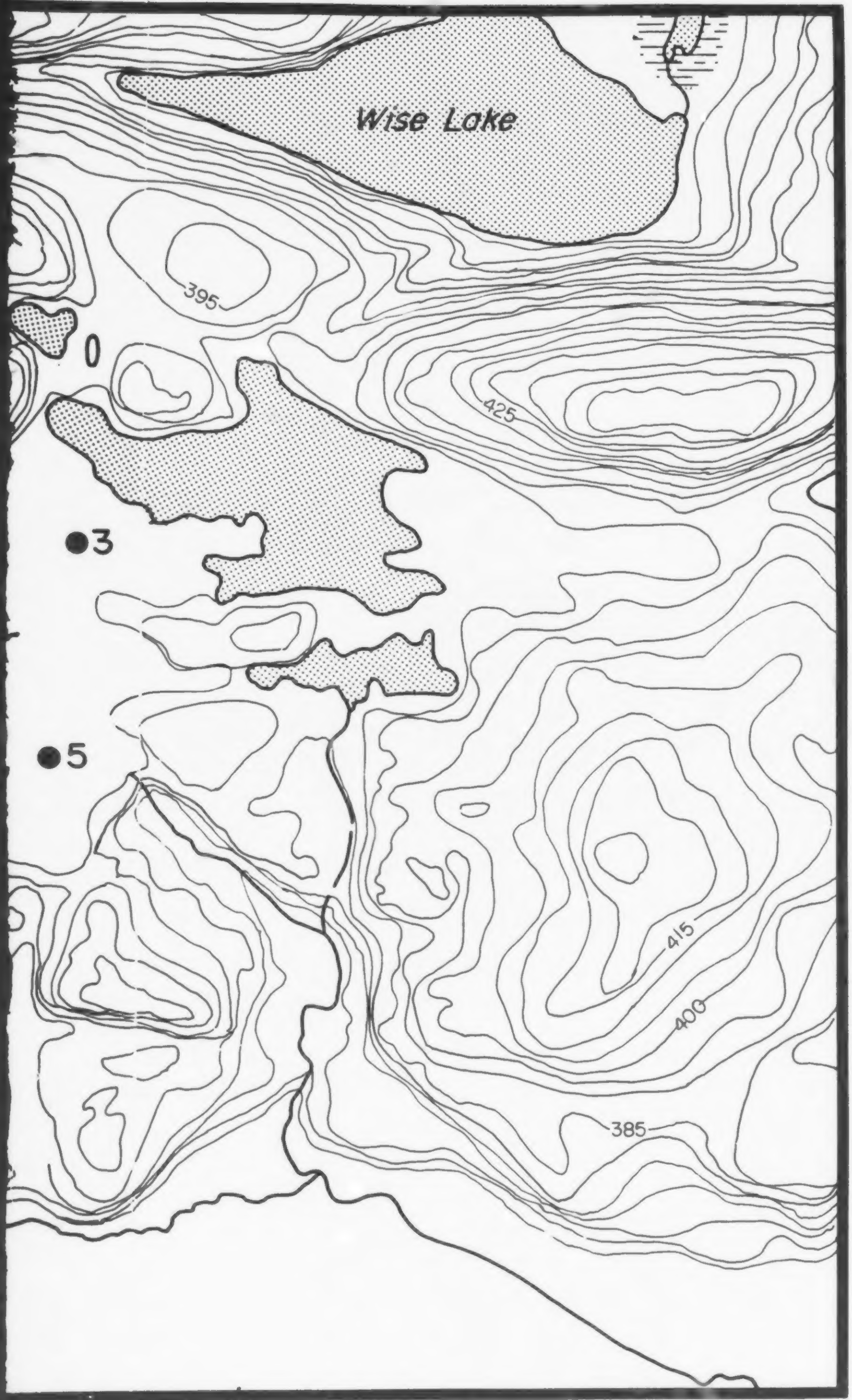
Field Procedures

A total of five cores were collected during the geotechnical field program conducted during March to April 1985. Bacterial sample location numbers correspond to borehole numbers as illustrated in Figure 4.2. All core samples were subdivided by depth. Depth ranges of samples provided for bacterial analysis were not continuous, but rather represented a range of depths from the tailings surface to the underlying till material. All samples were shipped at 4°C to the laboratory.

Laboratory Procedures

Of the five cores collected, only cores from Sites SO-04 and SO-05 were selected for bacterial analysis since these provided the most comprehensive depth coverage. All analyses were performed at the Microbiology Laboratory, University of Waterloo, under the direction of Dr. C. Mayfield. Analyses performed on each core subsample included:


415
400
405
425
Dumbell Lake
3
4
400
2
5
1
410
400
400
400
415
370


Wise Lake
395
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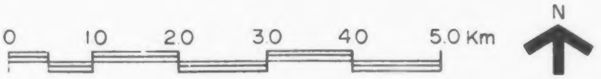
425
●3
●5
415
400
385

Figure 4.2 Biology

Bacterial Sampling Sites


0
1.0
2.0
3.0
4.0
5.0 Km
N

- Aerobic Plate Count
- Anaerobic Deep Tube Count
- Sulphate Reducing Bacteria Count
- Most Probable Number Sulphur-Oxidizers Estimate
- Most Probable Number Iron Oxidizers Estimate

The methods used to isolate and count the different categories of bacteria in the samples are described in Appendix 5.

QA/QC Program

Samples were transferred to sterile diluant in a laminar flow hood. This prevents atmospheric contamination. This method is usually only used in work with potentially hazardous microbes such as in biotechnology research, but was applied to the current study as an extra precaution. Control samples of diluants were processed to check for contamination. Some plates were also set aside uninnoculated as a further control. Normal bacterial aseptic methods were used throughout the analyses.

Data Presentation

The data are presented in Table 4.4.1. All results are presented as the number of bacterial cells per gram dry weight of material. Aerobic and anaerobic counts represent total number of bacteria per gram of sample. The sulphate reducers, sulphur oxidizers and iron oxidizers are estimates derived from Most Probable Number (MPN) counts per gram of material. For these MPN counts, the 95% confidence limits are provided in brackets. Where sample counts were either very low or very high, the 95% confidence interval could not be determined.

4.4.2 Vegetation - Biomass

Field Procedures

Above-ground biomass samples were collected from each major vegetation community on Lacnor. Only two community types, Birdsfoot Trefoil and Red Fescue, were adequately

TABLE 4.4.1: BIOLOGY - BACTERIAL COUNTS IN LACNOR TAILINGS (bacteria/g dry weight of material)

Site	Borehole	Sample Depth (m)	Soil Description	Aerobic Bacteria (total bacteria/g)	Anaerobic Bacteria (total bacteria/g)	Sulphate Reducing Bacteria (MPN/g) (95% Confidence Interval)	Sulphur Oxidizing Bacteria (MPN/g)	Iron Oxidizing Bacteria (MPN/g)
SO-04	C	0.1	Sand tailings (light grey)	1.1×10^{6}	2.8×10^{4}	L 20 (-)	4.6×10^{4} (7.1×10^{3}-2.4×10^{5})	4.3×10^{3} (700-2.1×10^{4})
SO-04	A	0.2	Sand tailings (light grey)	7.1×10^{4}	300	330 (110-930)	9.3×10^{3} (1.5×10^{3}-3.8×10^{4})	2.4×10^{5} (-)*
		0.6	Sand tailings with occasional silt-slime bands (medium grey)	L 100	L 187	L 20 (-)	240 (36-1.3×10^{3})	4.6×10^{4} (7.1×10^{3}-2.4×10^{5})
		6.1	Silt-slime tailings with occasional sand (medium dark grey)	5.7×10^{6}	2.2×10^{6}	3.5×10^{4} (1.2×10^{4}-1.0×10^{5})	9 (1-36)	23 (4-120)
		9.8	Silt-slime tailings (medium dark grey)	7.4×10^{6}	5.9×10^{5}	1.1×10^{4} (3.1×10^{3}-2.5×10^{4})	L 3 (-)	L 3 (-)
		10.0	Silty sand and gravel till (black)	3.2×10^{7}	7.6×10^{7}	G 2.4×10^{5} (-)	4.3×10^{3} (700-2.1×10^{4})	7.5×10^{3} (1.4×10^{3}-2.3×10^{4})
		10.7	Silty sand and gravel till (medium reddish-brown)	L 100	3.4×10^{2}	260 (90-780)	L 3 (-)	L 3 (-)
SO-05	B	0.8	Sandy tailings (light grey)	1.9×10^{3}	2.3×10^{3}	230 (70-700)	9.3×10^{3} (1.5×10^{3}-3.8×10^{4})	2.4×10^{5} (-)
		1.5	Sand-silt tailings (medium grey)	2.9×10^{3}	L 199	20 (L 5-70)	930 (150-3.8×10^{3})	G 2.4×10^{4} (-)
		13.9	Silty snd tailings (light dark grey)	5.6×10^{5}	2.9×10^{4}	210 (70-630)	2.4×10^{3} (360-1.3×10^{4})	23 (4-120)
		14.6	Peat (dark brown)	3.2×10^{7}	1.2×10^{6}	40 (L 5-110)	L 3 (-)	L 3 (-)
		16.5	Sand and gravel (medium grey)	1.4×10^{3}	4.7×10^{6}	790 (250-1.9×10^{3})	240 (36-1.3×10^{3})	G 2.4×10^{5} (-)

(-)* Confidence limits could not be derived due to very low or high numbers.

L = less than.

G = greater than.

represented for a statistically valid biomass sampling program. Two separate trefoil communities appeared to have distinctive growth characteristics and were thus sampled separately.

Samples were collected during the week of 29 July to 01 August 1985. Late July and early August generally corresponds to the period of peak biomass in central Ontario.

In each community, vegetation was collected from 10 to 15 randomly placed quadrats of 0.125 m^2 dimension. In each quadrat, all living plant matter was clipped at ground level and placed in paper bags for shipping.

Laboratory Procedures

All samples were oven-dried the day they were collected. Samples were placed in an oven set at 70°C and dried for 24 hours to a constant weight. Dried samples were weighed to the nearest 0.1 g and weights were converted to the dry weight/m^2 equivalent.

QA/QC Program

Random samples were obtained using a random number table. Collection of 10 to 15 replicates per community is generally considered adequate for obtaining a normal distribution in diverse biological communities (Green, 1979).

Data Presentation

Biomass data are presented in Table 4.4.2. For each community, individual replicate biomass values, as well as community averages and standard deviation, are presented. All biomass values are presented as gram dry weight/m^2.

TABLE 4.4.2: BIOLOGY - ABOVE-GROUND BIOMASS (g dry weight/m^2)

Community	Replicate Biomass Values (g dry weight/m^2)	Community Statistics	
Birdsfoot Trefoil 1	258.8	Number of Replicates:	16
	456.0		
	68.1	Mean:	276.2
	256.9		
	84.3	Range:	32.7-919.7
	919.7		
	148.7	Standard Deviation:	238.4
	431.1		
	133.7		
	269.1		
	254.9		
	32.7		
	665.7		
	104.6		
	160.7		
	174.3		
Fescue Grass	38.4	Number of Replicates:	17
	29.6		
	23.8	Mean:	38.4
	31.8		
	34.3	Range:	0-107.5
	37.9		
	75.7	Standard Deviation:	29.3
	107.5		
	41.2		
	43.5		
	33.7		
	2.1		
	0		
	23.2		
	12.7		
	22.1		
	94.9		
Birdsfoot Trefoil 2	442.7	Number of Replicates:	10
	999.6		
	504.9	Mean:	580.0
	753.1		
	204.1	Range:	204.1-999.6
	582.7		
	412.7	Standard Deviation:	250.8
	944.1		
	397.8		
	558.4		

4.4.3 Vegetation - Radionuclide Analysis

Field Procedures

A total of 26 composite samples of representative species were collected from various locations around the tailings and at several control sites as shown on Figure A4.3. All samples were collected between 29 July to 01 August 1985. Species collected include:

- Birdsfoot Trefoil
- Red Fescue
- Reed Canary Grass
- Birch
- Cattail
- Raspberry

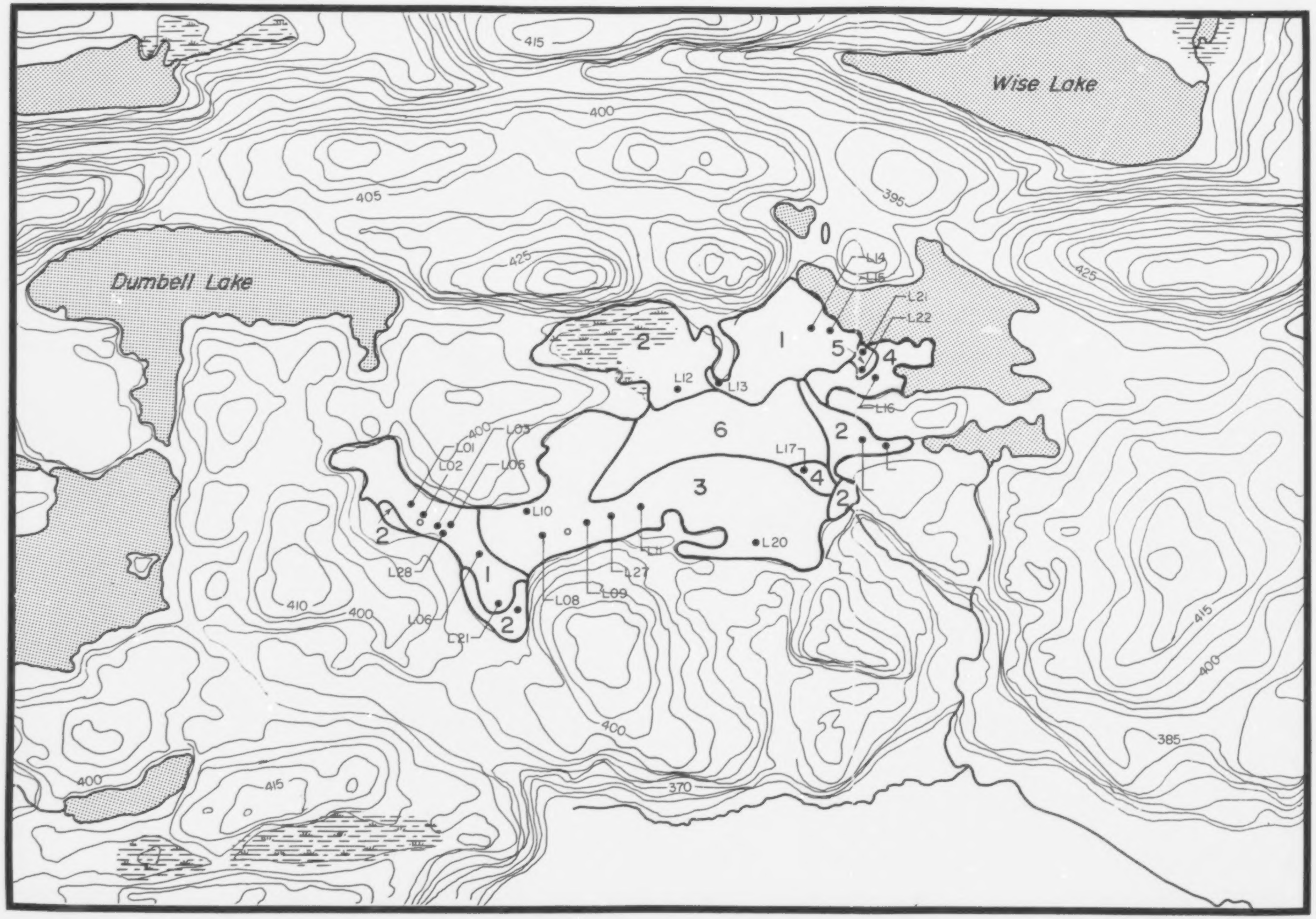
Table 4.4.3 is a key to species sampled, communities they were collected from and dry weights of samples. For each sample, with the exception of raspberries, above-ground parts of several plants located within close proximity to each other were collected. Only the raspberry fruit was collected for analysis. Samples were washed in tap water, rinsed in distilled water and air-dried prior to shipment to the laboratory.

Laboratory Procedures (Radionuclides)

Twenty-one samples were selected for analysis of U-238, Ra-226, Th-228, Th-230, Th-232 and Pb-210. Oven-dried samples were milled in a Wiley mill to -20 mesh. Analyses were performed at Chemex Laboratories, Vancouver, B.C. Three samples were split and sent to Monenco Laboratories for interlaboratory QA/QC. Methods employed by both laboratories and detection limits achieved are described in Appendix 5.

QA/QC Program

Three vegetation samples were split and analyzed for radionuclide and trace metal concentrations at both the prime analytical laboratories and independent QA/QC laboratories.


415
Wise Lake
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Dumbell Lake
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L17
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3
2
400
L03
L01
L02
L05
L10
L20
L11
2
L28
1
L27
L09
L08
L06
L21
2
410
400
415
400
400
385
400
415
370

Figure 4.3 Biology Vegetation Communities Sampled at Lacnor

1. BIRDSFOOT TREFOIL
2. CATTAIL
3. RED FESCUE - BIRDSFOOT TREFOIL
4. REED CANARY GRASS
5. RASPBERRY
6. BARE, UNVEGETATED TAILINGS

- ○ BIOMASS CLIPPINGS TAKEN WITHIN COMMUNITY
- • SAMPLING SITES FOR ANALYSIS

0 10 20 30 40 50 Km

N

In addition, Chemex Laboratories has its own quality assurance program involving interlaboratory quality assurance audits sponsored by CANMET, CCIW, Environment Canada Air Pollution Control Directorate, NRCC and Agriculture Canada.

To maintain intralaboratory quality control, Chemex Labs routinely analyzes standard reference materials with each batch of twenty samples. For projects of special importance such as environmentally-related projects, certified reference materials are analyzed wherever feasible, supplemented by in-house reference materials internally prepared by Chemex Labs. Certified reference materials available include those circulated by, amongst others, CANMET, U.S. National Bureau of Standards, U.S. Geological Survey, South African Bureau of Standards, the International Atomic Energy Agency, the National Research Council of Canada and Agriculture Canada.

All data entering the Chemex Labs data base are verified by double data entry. The data are initially entered by one data entry operator and then independently confirmed by a second data entry operator. If the two sets of data do not match exactly, any entry discrepancies are immediately listed by the computer and can be corrected.

For the radionuclides requested, precision and accuracy are expected to be within the following confidence intervals:

Element	Solutions (%)	Solids (%)
Uranium-238	15	5
Thorium-232	15	5
Radium-226	15	10
Lead-210	15	15

Chemex Labs performance on the CANMET CCRMP uranium tailings standards indicates that these levels can certainly be achieved. All radionuclide activities would be reported with uncertainties calculated for the 95% confidence limit.

Data Presentation

The key to sample species is presented on Table 4.4.3. Radionuclide analyses of vegetation are presented on Table 4.4.4. All results except uranium are presented as

TABLE 4.4.3: BIOLOGY - KEY TO RADIONUCLIDE AND TRACE METAL SAMPLES

Sample No.	Species	Community Designation	Dry Weight of Sample (g)
L01	Willow	1	21.55
L02	Reed Canary Grass	1	38.85
L03	Birch	1	20.45
L04	Red Fescue	1	38.15
L05	Clover	1	19.90
L06	Birdsfoot Trefoil	1	21.75
L07	Cattail	2	42.05
L08	Birch	3	26.00
L09	Birdsfoot Trefoil	3	33.00
L10	Reed Canary Grass	3	51.40
L11	Red Fescue	3	21.70
L12	Cattail	2	41.05
L13	Birdsfoot Trefoil	1	30.00
L14	Birdsfoot Trefoil	1	31.45
L15	Birch	1	25.50
L16	Reed Canary Grass	4	32.05
L17	Reed Canary Grass	4	31.80
L18	Reed Canary Grass	1	31.65
L19	Birdsfoot Trefoil	1	26.45
L20	Red Fescue	3	18.45
L21	Raspberry	5	8.60
L22	Raspberry	5	62.60
L23	Birch	off-tailings	22.05
L24	Birch	off-tailings	21.50
L25	Raspberry	Elliot Lake Townsite	29.00
L26	Cattail	Elliot Lake Townsite	29.40
L27	Soil Sample	3	
L28	Soil Sample	1	

TABLE 4.4.4: BIOLOGY - RADIONUCLIDE CONCENTRATION IN VEGETATION (*Second values are by QA/QC lab)

Sample Location No.	Vegetation Species	Community No.	U-238 (ug/g)	Ra-226 (Bq/g)	Th-228 (Bq/g)	Th-230 (Bq/g)	Th-232 (Bq/g)	Pb-210 (Bq/g)
L06	Birdsfoot Trefoil	1	0.02	0.503±0.018	0.012±0.007	0.039±0.01	0.012±0.007	0.09±0.01
L04	Red Fescue	1	0.21	0.642±0.02	0.002±0.002	0.007±0.005	0.002±0.002	0.16±0.02
L02	Reed Canary Grass	1	0.02	0.092±0.004	0.003±0.002	0.036±0.01	0.003±0.002	0.05±0.01
L03	Birch	1	0.04	1.590±0.031	0.002±0.002	0.022±0.008	0.002±0.002	0.02±0.01
L07	Cattail	2	0.12/ L 0.2*	0.090±0.004/ 0.10 (±0.01)	0.010±0.006/ L 0.01	0.013±0.007/ L 0.01	0.010±0.006/ L 0.01	0.04±0.01/ 0.80 (±0.05)
L09	Birdsfoot Trefoil	3	0.05	0.634±0.02	0.004±0.003	0.020±0.008	0.004±0.003	0.09±0.02
L11	Fed Fescue	3	0.27	0.525±0.018	0.007±0.004	0.017±0.007	0.007±0.004	0.12±0.02
L10	Reed Canary Grass	3	0.02/ L 0.2*	0.236±0.012/ 0.24 (±0.01)	0.005±0.003/ L 0.01	0.039±0.01/ L 0.01	0.005±0.003/ L 0.01	0.04±0.01/ 0.20 (±0.05)
L08	Birch	3	0.04	1.103±0.026	0.004±0.002	0.016±0.007	0.004±0.002	0.04±0.01
L12	Cattail	2	0.17	0.536±0.018	0.006±0.004	0.030±0.009	0.006±0.004	0.06±0.01
L13	Birdsfoot Trefoil	1	0.06	0.124±0.009	0.005±0.003	0.013±0.006	0.005±0.003	0.03±0.01
L15	Birch	1	0.10	0.496±0.017	0.006±0.004	0.030±0.009	0.006±0.004	0.05±0.01
L17	Reed Canary Grass	4	0.14	0.196±0.011	0.006±0.004	0.035±0.009	0.006±0.004	0.02±0.01
L19	Birdsfoot Trefoil	1	L 0.01	0.058±0.007	0.006±0.004	0.025±0.008	0.006±0.004	0.04±0.01
L18	Reed Canary Grass	1	0.04	0.476±0.017	0.006±0.004	0.029±0.008	0.006±0.004	0.04±0.01
L20	Red Fescue	3	0.22	0.945±0.024	0.010±0.007	0.037±0.01	0.010±0.007	0.18±0.02
L21	Raspberry	5	0.02	0.030±0.007	0.006±0.004	L 0.005	0.006±0.004	L 0.01
L22	Raspberry	5	0.05/ L 0.2*	0.008±0.002/ L 0.01	0.006±0.004/ L 0.01	L 0.005/ L 0.01	0.006±0.004/ L 0.01	L 0.01/ L 0.2
L23	Birch	Town	0.06	0.217±0.01	0.005±0.003	0.016±0.007	0.005±0.003	0.01±0.01
L25	Raspberry	Town	0.02	0.012±0.001	0.006±0.004	L 0.005	0.006±0.004	L 0.01
L26	Cattail	Town	0.07	0.026±0.004	0.006±0.004	L 0.005	0.006±0.004	L 0.01

± 95% confidence interval for counting.

Bq/g dry weight. U-238 concentrations are presented as ug/g. In cases where two values are provided, the second values represent analysis by the QA/QC laboratory.

4.4.4 Vegetation - Trace Metal Analysis

Fourteen of the dried, ground vegetation samples were analyzed for trace metals. Trace Metals analyzed include:

- aluminum
- arsenic
- barium
- beryllium
- cadmium
- calcium
- chromium
- cobalt
- copper
- iron
- lead
- magnesium
- manganese
- molybdenum
- nickel
- potassium
- selenium
- silver
- sodium
- strontium
- vanadium
- zinc

Analyses were performed at Barringer Magenta Laboratories, Rexdale, Ontario. Three samples were split and analyzed at Beak Analytical Services, Mississauga, Ontario, as part of the interlaboratory QA/QC program. Methods employed by both laboratories and detection limits achieved are described in Appendix 5.

Field Procedures

These were as discussed in Section 4.4.3

Laboratory Procedures

Oven-dried samples were milled in a Wiley mill to -20 mesh and then forwarded to the Barringer Magenta (prime) and BEAK (QA/QC) laboratories for analyses. Individual laboratory methods are described in Appendix 5.

QA/QC Program

Three vegetation samples were split and analyzed for metals at both of the prime and QA/QC laboratories. Both Barringer Magenta and BEAK have internal quality control programs with analysis of blind replicate samples. They both also participate in a variety of government-sponsored interlaboratory comparisons (Hart et al., 1985). Detection limits for the methods used are provided in Table 4.4.5.

Comparison of the results between the main laboratory and QA/QC laboratory for split vegetation samples indicates differences exceeding two times for 15 of the 22 parameters analyzed for both in cattails (of which two varied more than ten-fold), for 5/22 raspberry analyses (of which one exceeded ten-fold) and for 6/22 birch analyses (of which two exceeded ten-fold). Molybdenum analyses were ten-fold different for two and possibly more samples. However, the main laboratory reported at or below detection limits of 10 ug/g in all but one of the molybdenum analyses, while the QA/QC lab reported below detection limits of 0.3 ug/g. This indicates more of a difference in detection limits than in actual results (compare Tables 4.4.5 and 4.4.6). Dreeson et al. (1979) reported ranges of 100-fold for analyses of molybdenum in the 5 mg/L range in water by 15 laboratories with a 50% standard deviation. This level is close to the levels found in our study, but both laboratories indicated detection limits in solids are 20 to 50 times better than in waters. Arsenic concentrations reported by the two laboratories varied more than two-fold in all three samples as well. In all three cases, the QA/QC lab reported below detection levels, while the main lab reported higher levels. At similar levels in water from a uranium tailings leachate, Dreeson et al. (1979) reported a 48% standard deviation and ranges between 13 laboratories of 30 to 160 ug/L. Barium was also reported with differences exceeding two-fold in all three interlaboratory samples. No relevant reference studies were found.

Results of analyses of an orchard leaf standard sample provided by the QA/QC laboratory (BEAK) showed a four times interlaboratory difference for molybdenum and slightly over two times for cobalt, with all other parameters equal or within the two-fold range. The laboratory considers these indicators of good precision.

A review of the results of a number of interlaboratory analyses of trace metals in vegetation samples indicates that, at environmental, near detection limit levels, results within ±50% are generally considered acceptable within the accuracy of equipment available. This means that if one laboratory reports at the low end and the second at the high end, a two times difference in results could result. In this study, two of the replicate analyses for vegetation (lead and barium) within the same laboratory resulted in

TABLE 4.4.5: BIOLOGY - DETECTION LIMITS FOR ICAP ANALYSIS
(in solution, digestion of solids increases this by 20 to 50 times)

Element	Detection Limit (mg/L)
Aluminum	0.05
Barium	0.005
Beryllium	0.0005
Boron	0.004
Cadmium	0.01
Calcium	0.05
Chromium	0.01
Cobalt	0.05
Copper	0.01
Iron	0.01
Magnesium	0.01
Manganese	0.01
Molybdenum	0.2
Nickel	0.05
Potassium	1.0
Phosphorus	0.5
Silver	0.005
Sodium	2.0
Strontium	0.001
Thorium	0.05
Titanium	0.005
Vanadium	0.005
Zinc	0.05
Zirconium	0.02

TABLE 4.4.6: BIOLOGY - DETECTION LIMITS FOR ANALYSIS PERFORMED AT BEAK ANALYTICAL SERVICES

(for solution, limits for solids are 20 to 50 times higher)

Element	Detection Limit (mg/L)
Aluminum	0.01
Arsenic	0.0005
Barium	0.005
Beryllium	0.005
Cadmium	0.005
Calcium	0.01
Chromium	0.005
Cobalt	0.005
Copper	0.005
Iron	0.01
Lead	0.01
Magnesium	0.01
Manganese	0.005
Molybdenum	0.01
Nickel	0.005
Potassium	0.01
Selenium	0.0005
Silver	0.01
Sodium	0.01
Strontium	0.005
Vanadium	0.005
Zinc	0.005

slightly over the two-fold difference range (Table 4.4.7). In both cases, results were about ten times the reported detection limits (Table 4.4.6) for the method used.

In conclusion, we can only echo the recommendation emphasized by several authors of papers comparing interlaboratory accuracy in trace metal analyses (Hume, 1973; van Loon, 1974; Dreeson et al., 1979) that, for trace environmental concentrations, one cannot rely heavily on analyses from a single sample. In most cases, at least six replicate samples of the same substance, sampled under the same conditions and analyzed by the same method are recommended by these authors.

Data Presentation

Metal concentrations in vegetation from the Lacnor site are presented on Table 4.4.7. Concentrations are expressed as ug/g dry weight. An initial review of data indicates that values are more species related than location related. Soils samples from the root zone of communities (1) Birdfoot Trefoil and (3) Red Fescue are presented in the next section. Duplicate results from the QA/QC laboratory are asterisked in Table 4.4.7.

4.4.5 Soils

Field Procedures

Two composite soil samples were collected for analyses of radionuclides and trace metals. Samples were collected from the root zone (5 to 15 cm) in the Birdsfoot Trefoil and Red Fescue vegetation communities as shown on Figure 4.3. Samples were air-dried prior to shipment to the laboratory.

Laboratory Procedures

All soil samples were oven-dried, then ring-ground to -100 mesh in a pack and ring grinder. Radionuclide analyses were performed at Chemex Laboratories, Vancouver, B.C. Parameters analyzed include U-238, Ra-226, Th-228, Th-230, Th-232 and Pb-210.

TABLE 4.4.7: BIOLOGY - TRACE METAL CONCENTRATIONS IN VEGETATION (ug/gm)

Sample Location Number	Vegetation Species (Community No.)		Aluminum (ug/g)	Arsenic (ug/g)	Barium (ug/g)	Beryllium (ug/g)	Boron (ug/g)	Cadmium (ug/g)	Calcium (ug/g)	Chromium (ug/g)	Cobalt (ug/g)	Copper (ug/g)	Iron (ug/g)	Lead (ug/g)
L04	Red Fescue	(1)	161	0.14	7.9	L 0.02	2.7	0.6	2,450	L 0.5	L 3	18.0	247	20
L03	Birch	(1) *	32.6 42	0.09 L 0.01	11.5 1.9	L 0.02 L 0.1	8.1 -	0.5 0.6	5,010 4,200	L 0.5 0.5	3 8.7	16.5 18.1	67.8 70	L 3 6.2
L07	Cattail	(2)	30.4	0.20	0.4	L 0.02	3.4	L 0.5	3,480	L 0.5	L 3	2.1	1,050	L 3
L11	Red Fescue	(3)	130	0.24	9.3	L 0.02	2.1	L 0.5	2,370	L 0.5	L 3	19.7	565	L 3
L10	Reed Canary Grass	(3)	23.4	0.13	1.8	L 0.02	2.5	L 0.5	1,800	L 0.5	L 3	8.6	47.6	3
L08	Birch	(3)	28.8	0.07	5.7	L 0.02	6.7	0.5	543.0	0.8	6	11.3	84.4	L 3
L12	Cattail	(2) *	33.1 20	0.16 L 0.01	2.2 1.1	L 0.02 L 0.1	4.4 -	L 0.5 0.2	7,210 3,400	0.8 0.4	4 0.7	5.4 2.4	86.5 52	L 3 3.3
L19	Birdsfoot Trefoil	(1)	11.4	0.03	1.1	L 0.02	7.7	L 0.5	13,200	L 0.5	L 3	7.7	58.4	L 3
L18	Reed Canary Grass	(1)	16.2	0.04	3.4	L 0.02	2.4	L 0.5	1,890	0.6	L 3	10.9	37.0	L 3
L20	Red Fescue	(3)	112	0.23	16.5	L 0.02	3.4	L 0.5	2,670	L 0.5	L 3	15.6	336	L 3
L22	Raspberry	(5) *	67.1 76/75	0.05 L 0.01/ L 0.01	14.5 3.8/1.8	L 0.02 L 0.1/ L 0.1	6.2 -	0.7 1.1/0.6	2,290 2,400/ 2,100	L 0.5 1.0/0.2	L 3 1.3/0.8	14.2 14.8/ 14.7	36.0 39/33	L 3 6.9/3.2
L23	Birch	(Town)	34.5	0.03	7.5	L 0.02	9.1	L 0.5	6,290	L 0.5	L 3	18.9	61.2	L 3
L25	Raspberry	(Town)	105	0.04	12.1	L 0.02	6.4	0.8	2,380	L 0.5	L 3	11.2	29.3	L 3
L26	Cattail	(Town)	19.6	0.05	37.8	L 0.02	4.7	L 0.5	9,640	0.7	L 3	6.4	91.2	L 3

TABLE 4.4.7: BIOLOGY - TRACE METAL CONCENTRATIONS IN VEGETATION (ug/gm)

Sample Location Number	Vegetation Species (Community No.)		Magnesium (ug/g)	Manganese (ug/g)	Molybdenum (ug/g)	Nickel (ug/g)	Potassium (ug/g)	Phosphorus (ug/g)	Selenium (ug/gm)	Silver (ug/gm)	Sodium (ug/gm)	Strontium (ug/gm)	Titanium (ug/gm)
L04	Red Fescue	(1)	1,480	52.0	L 10	4	6,550	2,070	0.13	L 0.3	L 50	3.74	6.4
L03	Birch	(1) *	2,590 2,900	43.8 59	L 10 L 0.3	4 4.0	8,590 7,200	2,500 -	0.08 0.06	L 0.3 3.3	L 50 75	2.16 2.1	1.6 -
L07	Cattail	(2)	1,250	211	L 10	L 3	17,400	1,430	0.15	1.0	310	6.11	0.5
L11	Red Fescue	(3)	1,790	37.9	L 10	3	8,700	1,850	0.27	L 0.3	L 50	2.82	6.3
L10	Reed Canary Grass	(3)	2,130	39.6	L 10	4	9,860	920	0.81	L 0.3	L 50	1.21	0.6
L08	Birch	(3)	2,860	35.2	L 10	4	9,590	2,560	0.12	L 0.3	L 50	1.69	1.9
L12	Cattail	(2) *	1,950 900	338 284	10 L 0.3	6 1.5	19,500 6,400	1,080 -	0.81 0.36	0.6 L 0.1	180 85	7.51 3.4	0.4 -
L19	Birdsfoot Trefoil	(1)	2,510	9.5	30	8	11,900	1,850	0.09	L 0.3	L 50	7.16	0.9
L18	Reed Canary Grass	(1)	1,410	115	L 10	5	16,500	1,560	0.48	0.6	L 50	2.02	1.1
L20	Red Fescue	(3)	1,470	183	L 10	3	9,420	1,380	0.50	L 0.3	L 50	2.93	5.4
L22	Raspberry	(5) *	1,470 1,530/ 1,390	114 151/123	10 L 0.3/ L 1.3	4 3.4/3.1	8,850 5,600/ 7,400	1,960 -	0.02 L 0.01/ L 0.01	L 0.3 0.4/ L 0.1	70 59/61	12.9 14.4/ 14.3	0.7 -
L23	Birch	(Town)	1,580	158	L 10	7	8,460	2,420	0.02	L 0.3	L 50	9.81	0.3
L25	Raspberry	(Town)	1,420	27.9	L 10	3	9,540	1,470	L 0.01	L 0.3	L 50	11.9	0.3
L26	Cattail	(Town)	994	1,270	L 10	4	21,300	1,160	0.04	0.7	4,420	41.7	0.3

TABLE 4.4.7: BIOLOGY - TRACE METAL CONCENTRATIONS IN VEGETATION (ug/gm)

Sample Location Number	Vegetation Species (Community No.)		Vanadium (ug/gm)	Zinc (ug/gm)	Zirconium (ug/gm)
L04	Red Fescue	(1)	L 0.3	21	L 3
L03	Birch	(1)	L 0.3	62	L 3
		*	0.3	74	-
L07	Cattail	(2)	L 0.3	11	L 3
L11	Red Fescue	(3)	0.8	19	L 3
L10	Reed Canary Grass	(3)	0.4	11	L 3
L08	Birch	(3)	0.5	49	L 3
L12	Cattail	(2)	L 0.3	9	L 3
		*	0.2	3.7	-
L19	Birdsfoot Trefoil	(1)	L 0.3	11	L 3
L18	Reed Canary Grass	(1)	0.8	18	L 3
L20	Red Fescue	(3)	0.4	14	L 3
L22	Raspberry	(5)	0.9	24	L 3
		*	0.3/0.3	32/27	-
L23	Birch	(Town)	L 0.3	33	L 3
L25	Raspberry	(Town)	1.0	24	L 3
L26	Cattail	(Town)	L 0.3	16	L 3

* Replicate analysis by QA/QC laboratory.

L = less than.

residue. Analytical procedures were identical to those employed in the vegetation analysis.

Soil samples were analyzed for the following trace metals:

aluminum
arsenic
barium
beryllium
cadmium
calcium
chromium
cobalt
copper
iron
lead
magnesium
manganese
molybdenum
nickel
potassium
selenium
silver
sodium
strontium
vanadium
zinc

Metals analyses were performed by Barringer Magenta. Their analytical methods are described in Appendix 5.

QA/QC

Both Chemex and Barringer Magneta have internal quality assurance/quality control programs including blind replicates and involvement in government interlaboratory quality assurance programs. The 95% confidence intervals for radiochemical analyses relate to counting statistics only and do not consider potential subsample variances. No duplicate analyses of soils were performed in this study. The QA/QC program for this study is detailed in Appendix 5.

Data Presentation

Soils analytical results are presented in Tables 4.4.8 (radionuclides) and 4.4.9 (metals). Concentrations of radionuclides are expressed as Bq/g dry weight, except for uranium which is expressed as ug/g dry weight. Metals concentrations are reported as ug/g dry weight.

TABLE 4.4.8: BIOLOGY - RADIONUCLIDE CONCENTRATIONS IN SOILS

Sample Location Number	Community	U-238 (ug/g)	Ra-226 (Bq/g)	Th-228 (Bq/g)	Th-230 (Bq/g)	Th-232 (Bq/g)	Pb-210 (Bq/g)
L-27	3	6.0	3.87±0.13	0.07±0.02	0.62±0.05	0.07±0.02	1.25±0.04
L-28	1	6.5	2.18±0.10	0.07±0.02	0.41±0.05	0.07±0.02	1.15±0.03

TABLE 4.4.9: BIOLOGY - METALS CONCENTRATIONS IN SOILS (ug/g dry weight)

Sample		Concentrations in ug/g Dry Weight										
Number	Community	Aluminum	Arsenic	Berylium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium
L-27	3	25,300	3.72	0.47	L 1	1,130	235	L 5	18.4	5,440	135	1,250
L-28	1	25,200	3.86	0.54	L 1	1,270	252	5	22.6	5,600	160	1,390

Sample		Concentrations in ug/g Dry Weight								
Number	Community	Manganese	Molybdenum	Nickel	Phosphorus	Potassium	Selenium	Strontium	Thorium	Titanium
L-27	3	16	L 20	L 5	120	18,700	0.538	17.8	36	849
L-28	1	17	L 20	6	150	18,000	0.577	18.0	51	945

Sample		Concentrations in ug/g Dry Weight		
Number	Community	Vanadium	Zinc	Zirconium
L-27	3	17.7	15	49
L-28	1	18.6	15	52

4.4.6 Mammals

Field Procedures

Five beavers were trapped in the Lacnor area by local trappers over the summer of 1985. Flesh and molar samples were collected by Mr. R. Lipinski of Rio Algom Limited. These were frozen and stored until fall when they were shipped in a picnic cooler with ice to Chemex Laboratories in Vancouver for radionuclide analyses. These were analyzed for age estimates by Mr. M. Novak, Fur Coordinator, Ontario Ministry of Natural Resources. Data on ages, trapping locations and fresh weights were determined in the field and supplied by Mr. Lipinski.

Laboratory Procedures

Samples were weighed fresh and dried overnight at 105°C. At that time, the partially dry samples were homogenized in a blender and dried for an additional 24 hours, cooled in a desiccator and weighed. The dry samples were then gradually charred and ashed at 550°C to yield a pale grey residue. The residue was cooled and weighed, and portions of the ash were digested with a mixture of hot nitric, perchloric and hydrofloric acids to yield a clear digest. Otherwise, laboratory procedures were as described for Chemex Laboratories solids analyses in Appendix 5.

With exceptions of very young animals, the ages of dead beavers can best be estimated by microscopically counting the layering in the cementum of molars. Each annual layer consists of a relatively broad summer layer and a usually lighter coloured winter deposit. Animals younger than two years are aged using distinguishing characteristics of teeth size and shape, as well as weight characteristics. The smallest beaver sampled was 11.3 kg indicating an age of at least 1 1/2 to 2 1/2 years (Larson and Van Nostrand, 1968). The aging by teeth method has been developed for Canadian beavers by Van Nostrand and Stephenson (1964). Details on methods used are presented in this latter publication while alternative methods are described and compared in the former.

QA/QC

Chemex Laboratories have an internal quality assurance/quality control program which is described in Appendix 5. No duplicate samples were analyzed.

TABLE 4.4.10: BIOLOGY - RESULTS OF RADIONUCLIDE ANALYSES OF BEAVER SAMPLES FROM LACNOR AREA
(Results reported on a wet weight basis)

Beaver No.	Location Trapped	Sex	Age (yr)	Wet Weight (kg)	% Water	U-238 (ug/g)	Ra-226 (Bq/g)	Th-228 (Bq/g)	Th-230 (Bq/g)	Th-232 (Bq/g)	Pb-210 (Bq/g)
1	West Nordic Pond	M	8 1/2-9	12.3	78.0	0.0014	0.002± 0.0007	L 0.0003	L 0.0003	L 0.0003	0.001± 0.001
2	Sheriff Creek Park	F	2 1/2-3	14.5	75.4	0.0059	0.0026± 0.0008	L 0.0003	0.001± 0.0005	0.0007± 0.0004	L 0.001
5	Elliot Lake Area Pond	F	1 1/2-2	14.5	60.9	0.0015	0.0019± 0.0005	0.0003± 0.0003	0.0003± 0.0003	0.0004± 0.0003	0.003± 0.002
6	Elliot Lake Area Pond	M	1 1/2-2	11.3	70.8	0.0018	0.0014± 0.0005	L 0.0003	0.0008± 0.0004	L 0.0003	0.002± 0.002
7	Elliot Lake Area Pond	M	1 1/2-2	12.7	55.8	0.0007	0.0006± 0.0003	0.0003± 0.0003	0.0003± 0.0003	L 0.0003	L 0.001

L = less than.

± 95% confidence interval for counting.

Data Presentation

Radionuclide concentrations, ages, sexes and fresh weight of beavers analyzed are presented in Table 4.4.10. Results are expressed as Bq/g dry weight, except for uranium concentrations which are expressed as ug/g dry weight.

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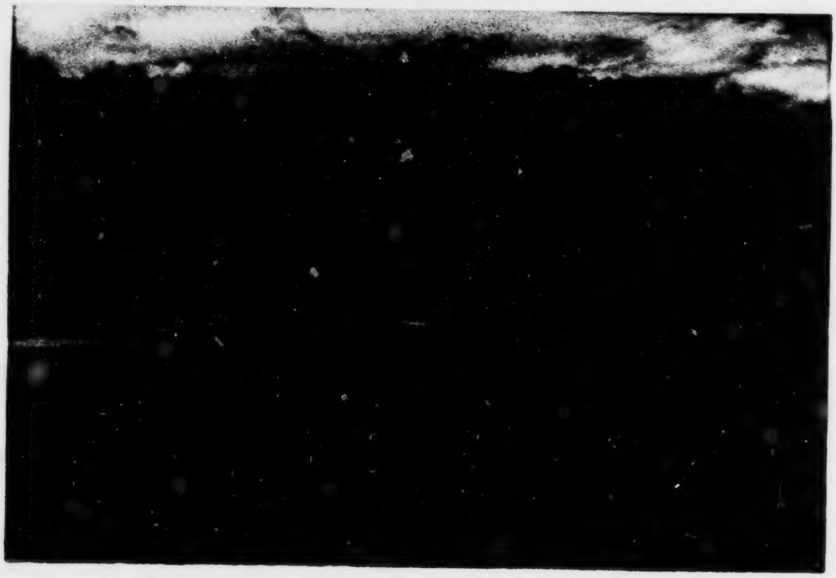
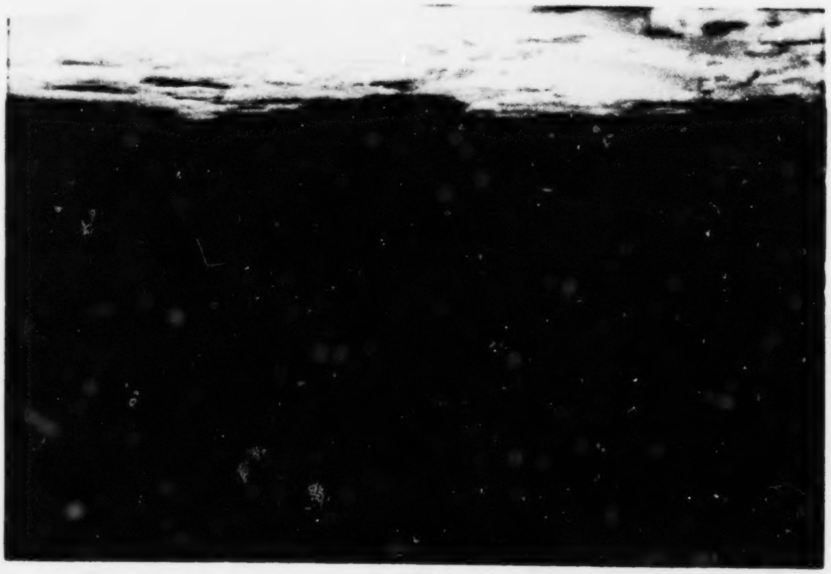
Raspberry Patch - southwest edge of tailings



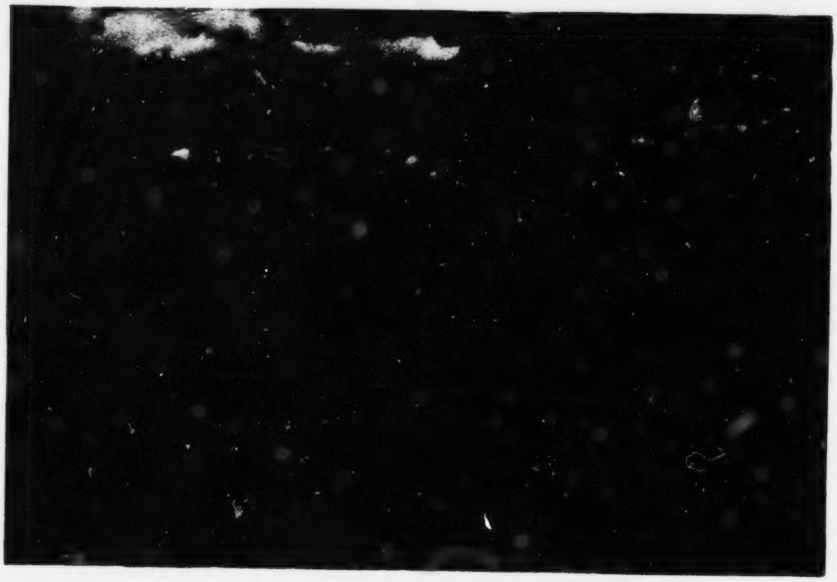
Cattail Marsh - north edge of tailings

Birdsfoot Trefoil Community - west end of tailings



Red Fescue-Birdsfoot Trefoil Community - west central tailings

Reed Canary Grass - east edge of tailings



Bare Unvegetated Tailings - northeast edge of tailings

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Numéro

5

CONTRACT SERIAL NO. OSQ84-00196
CONTRACTOR: Golder Associates
REQUISITION NUMBER: 23241-4-1680

LACNOR FIELD STUDY
ELLIOT LAKE, ONTARIO

APPENDIX 5
LABORATORY FACILITIES AND CHEMICAL METHODS

Prepared for

The National Uranium Tailings Program

By

Golder Associates
Beak Consultants SENES Consultants
Cumming - Cockburn & Associates

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THE LACNOR FIELD STUDY

The Lacnor Field Study consists of 6 volumes, each published separately. The main summary report is supplemented by the following five Appendices:

- o Appendix 1 - Geohydrology and Geochemistry
- o Appendix 2 - Meteorology and Air Quality
- o Appendix 3 - Surface Water Studies
- o Appendix 4 - Biology
- o Appendix 5 - Laboratory Facilities and Chemical Methods

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APPENDIX 5 LABORATORY FACILITES AND CHEMICAL METHODS

5.0 INTRODUCTION

Chemical analyses were carried out on a wide range of environmental materials including tailings solids, the porewater in contact with these solids, the surface waters draining the tailings, the porewater in contact with the geological materials underlying the tailings, vegetation growing on and in the immediate proximity of the tailings, dust eroded by wind from the tailings surface, and radon degassed from the tailings. All of these different environmental compartments, comprising a wide range of environmental matricies, were analyzed for major and trace stable elements and radionuclides of the U-238 and Th-232 decay series.

In this appendix, the laboratory facilities, analytical methods and internal quality assurance program of the different laboratories are described. External quality control (blind replicates, duplicate samples submitted to difference laboratories) are described in the appropriate section in the Appendices. Analytical results of the laboratory QC program are also given in this Appendix.

The laboratories described in this appendix (See Table 5.1) are Barringer Magenta Ltd. and Beak Analytical Services for major cations and anions; and Chemex Laboratories, Monenco Analytical Laboratories and Saskatchewan Research Council (SRC) Laboratories for radiochemical analysis. Barringer Magenta was the primary laboratory for major elements for all environments (surface water, porewater, tailings solids, vegetation, atmospheric dust) while Beak Analytical Laboratories was used as a check laboratory for interlaboratory comparison. Beak Analytical Services was the prime laboratory for early analyses of the surface water. Chemex Laboratories was the primary laboratory for porewater, tailings solids, vegetation and atmospheric dusts. Monenco Analytical Laboratories was the primary laboratory for surface water measurements. Monenco was used as the check laboratory for porewater, tailings solids, vegetation, and atmospheric dust while SRC and Chemex were used as check laboratories for the surface water program.

TABLE 5.1(a) FIELD MEASUREMENTS AND ASSOCIATED FIELD INVOLVEMENT

Environment	Sampling Responsibility	Laboratory Involvement Parameters	Primary Laboratory	Check Laboratory
Tailings Solids	Golder	Major Radionuclide	Barringer Chemex	Beak Monenco
Tailings Porewater	Golder	Major Radionuclide	Barringer Chemex	Beak Monenco
Surface Water	Beak	Major Radionuclide	Barringer Monenco	Beak Chemex SRC
Biological and Vegetation Tissues	Beak	Major Radionuclide Bacteria	Barringer Chemex Waterloo	Beak Monenco
High Vol Filters	Senes	Major Radionuclides	Barringer Chemex	Beak Monenco
Radon Monitoring	Senes	-	-	-

General Comment of Quality Assurance Program

Definition

Quality assurance comprises all those planned and systematic actions necessary to provide adequate confidence in the results of a monitoring program. Quality control comprises those quality assurance actions that provide a means to control and measure the characteristics of measurement equipment and processes to established requirements.

Quality assurance is the total program for assuring the reliability of monitoring data.

Quality control is the routine application of procedures for controlling the measurement process. Quality assurance includes aware personnel, proper instrumentation, analytical methods, quality control, record keeping and management support.

Analytical Repeatability

Analytical repeatability (also called precision), is the ability of the laboratory to reproduce the same value for the same sample sub-divided into independent test portions. Repeatability is generally limited by one of the following factors, in order of increasing significance.

- electronic (instrument) noise observed under extreme range expansion,
- inability to observe small changes in reading because of insufficient range expansion,
- analytical noise, e.g., non-reproducible colour development or noisy reagent background, independent of sample preparation procedures,
- sample preparation noise, e.g., poor repeatability after sample digestion,
- sample non-homogeneity,
- poor sampling or sample handling and preservation.

With respect to terminology, the following ISO/REMCO definitions have been adopted:

- **Analytical repeatability** involves the laboratory subdividing the same sample into independent test portions and analyzing it as two samples
- **Interlaboratory programs** where the different laboratories analyze the same sample, measure **reproducibility** and can be used to monitor accuracy of the methods.

Quality control and performance evaluation attempt to minimize and quantify the scatter of data resulting from the analytical measurements. The following data base is useful:

- results of duplicate analysis of samples split at the laboratory for use in assessing in-lab precision,

- results of duplicate samples submitted "blind" from the field (e.g., a sample split in two in the field) for assessing the additional effect of field activities and sample type, or perishability, on precision,

- results of duplicate samples where one is analyzed "blind" by the primary laboratory, and the other forwarded to a second laboratory for analyses during the same time frame.

Detection limit and precision statements are advisory in nature. Field and/or time variability usually do not permit application of these concepts to assist the data user in interpreting his results unless in fact analytical effects are limiting.

The stated values (given for example for BEAK in Table 5.1b) are achievable provided that major ions do not cause analytical interferences. Examples of interferences include the following. If one species dominates, colourimetric or spectral interference may result during cation-anion analysis or an energy interference duing radionuclide analysis. Spectral interferences occur when the interfering ion has a peak on the spectrum at the same or overlapping location as the primary ion of interest. Suitable dilutions for such interferences are necessary and may improve the detection limit. But dilution may also remove the ion of interest from its detectable range. Dilutions are also used to check for linearity.

Lower detection limits and lower method sensitivity (good precision and accuracy) require additional test runs on undiluted and/or spiked samples or may be enhanced by extraction/separation/concentration techniques. In some cases, the swamping effects cannot be overcome by other specific procedures available to normal laboratories. In some cases, special methods may allow the laboratory to go below the best stated detection limits given in Table 5.1.

If the user requires data with better precision or lower detection limits, the user should consult the laboratory to see whether the analytical system can be adapted to his needs.

Analytical Accuracy

Accuracy measures the bias which has been found, relative to some reference or established true value. If precision is sufficiently poor, bias will be difficult to detect; however, its influence on averaged data will still be real.

Analytical accuracy is determined by processing calibration and test reference materials at the same time that the routine samples are analyzed. It has been found that standards used to produce calibration curves and reference samples must have similar matrices to ensure that the instrument responds similarly to the interferences from the matrix. Reference materials are used for certain parameters that normally need correction for bias.

Laboratory Assurance Programs

Experience has shown that quality assurance programs must monitor internal laboratory performance on a continuous basis to ensure accurate and repeatable data. The following routine procedures may be included in analytical studies.

- Use certified reference materials.
- Use reference solutions to check bias.
- Use in-house standards prepared from CRM's to check bias.
- Process internal replicates.

TABLE 5.1(b) ANALYTICAL METHODOLOGY SURVEY – OPERATING CHARACTERISTICS OF METHODS

TYPE OF SAMPLE: Water

Parameter	Units of Measurement	Routine Analytical Operating Range Upper	Lower High	Lower Low	Best Method Lowest Reported	Method	Sample Preparation Laboratory Nomenclature	Bias (versus true value)	Literature Reference
pH	units	0-14	0.1	0.05	0.01	Meter	Probe*	-	APHA 423, 1983
Acidity ($CaCO_3$)	mg/L	500	1	0.5	0.5	Meter	Titration*	-	APHA 402, 1983
Alkalinity ($CaCO_3$)	mg/L	500	1	0.5	0.5	Meter	Titration*	-	APHA 403, 1983
Conductivity	umhos/cm	wide	1	0.1	0.1	Meter	Probe*	-	APHA 205, 1983
Total Dissolved Solids	mg/L	wide	1	0.5	0.5	105°C	Filter GFC 1.2 u	high/low	APHA 209C, 1983
DOC	mg/L	50	1	0.5	0.5	Analyser	Filter GFC 1.2 u	high/low	BOM 1
DIC	mg/L	50	1	0.5	0.5	Analyser	Filter GFC 1.2 u	high/low	BOM 1
Kjeldahl-N	mg/L	2	0.1	0.02	0.01	Nessler	Digestion HgO/Distillation	high	APHA 421 Modified, 1983
Major Anions	mg/L								
Bromide		200	1	0.1	0.05	IC	Filtered, DIONEX	-	DOM
Chloride		35	0.5	0.1	0.1	IC	Filtered, DIONEX	-	DOM
Fluoride		20	0.1	0.01	0.003	IC	Filtered, DIONEX	-	DOM
O-Phosphate		300	0.2	0.05	0.01	IC/$SnCl_2$	Dissolved, reactive P	low	DOM, APHA 424, 1983
Sulphate		200	1	0.2	0.05	IC	Filtered, DIONEX	-	DOM
Nitrate		200	0.1	0.01	0.01	IC/Brucine	Filtered, DIONEX	low/high	DOM, APHA 213C, 1971
Nitrite		100	0.2	0.01	0.001	IC	Filtered, DIONEX	-	DOM
Major Cations	mg/L								
Magnesium		400	0.1	0.01	0.005	DCP	Field Filtered, Acidified	-	BOM2
Calcium		400	0.2	0.05	0.02	DCP	Field Filtered, Acidified	Low	BOM2
Iron		200	0.02	0.01	0.005	DCP	Field Filtered, Acidified	-	BOM2
Manganese		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Silica		100	0.1	0.05	0.02	DCP	Field Filtered, Acidified	-	BOM2
Aluminum		100	0.1	0.01	0.05	DCP	Field Filtered, Acidified	-	BOM2
Sodium		200	0.2	0.1	0.05	DCP	Field Filtered, Acidified	-	BOM2
Potassium		100	0.1	0.02	0.01	DCP	Field Filtered, Acidified	-	BOM2
Trace Cations	mg/L								
Strontium		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Lead		100	0.02	0.01	0.005	DCP	Field Filtered, Acidified	high	BOM2
Cobalt		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Nickel		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Zinc		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Chromium		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Copper		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Cadmium		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	high	BOM2
Barium		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Vanadium		2	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Titanium		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM2
Arsenic	ug/L	10	1	0.5	0.2	FAA	Field Filtered, Acidified	-	Anal. Chim. Acta 93 p. 61, 1977
Selenium	ug/L	10	1	0.5	0.2	FAA	Field Filtered, Acidified	-	Anal. Chim. Acta 93 p. 61, 1977
Molybdenum		20	0.01	0.005	0.002	DCP	Field Filtered, Acidified	-	BOM 2
Beryllium		2	0.01	0.005	0.002	DCP	Field Filtered, Acifified	-	BOM 2

BOM1 - Beckman Operations Manual (TOC Analyser)
APHA - Standard Methods for the Examination of Water and Wastewater, 15th Ed.
* Samples as received, unfiltered in laboratory

BOM2 - Beckman Operations Manual (DCP)
DOM - Dionex Operations Manual

- Process blind replicates.
- Carry out spiking to eliminate interferences and confirm recovery.
- Balance the anion and cation ratio (if applicable).
- Interlaboratory cross-checks. Several external checks are carried out each year by the different laboratories. This information is used to monitor accuracy of methods and any bias. This information is available if requested.

5.1 Beak Laboratories

Beak Laboratories (Mississauga, Ontario) was the main check laboratory for non-radionuclide parameters for all environments (porewater, tailings solids, vegetation, dust, surface water) and analyzed surface water samples early in the program (to the end of March 1985), until all subcontracting arrangements were in place.

5.1.1 Laboratory Methods of Analysis (Beak Laboratories)

With a few exceptions detailed below, the chemical analyses described in this section were performed upon liquid samples. For cases where solid samples were analyzed, the solid samples were dissolved into a liquid phase using an appropriate digestion procedure.

With the exception of the DCP metals scan and the IC methods for 7 anions (NO_3^-, NO_2^-, SO_4^{2-}, $PO_4^{3=}$, Cl^-, Br^-, F^-), the analytical methods used are well established, published methods whose development and application in similar aquatic and solids samples have been used for approximately a decade. The methods are described in detail in (i) APHA (1983: Standard Methods for the Examination of Water and Wastewater), (ii) Environment Canada (1979: Analytical Methods Manual) and (iii) Allen, et al (1974: Chemical Analysis of Ecological Materials").

Table 5.1 describes the operating characteristics of the methods. A summary of the methods is given below; an overview of the methods is given in Table 5.2. The majority of the cationic (metals and elemental) analyses were done on the DCP instrument except mercury by cold vapour flameless AA and arsenic and selenium by hydride evolution and flameless AA.

(i) Alkalinity/Acidity - Liquids

Alkalinity was measured by titration of a portion of the sample to pH 4.5 with standardized sulphuric acid and then to pH 4.2 under the laboratory atmosphere. Acidity was determined by titration to pH 8.3 with standardized sodium hydroxide. In both cases a Radiometer pH meter was used after calibration with pH 4 and 10 buffers. These end points are appropriate for aqueous samples such as those of tailings which contain of the order of 5-10 mg TIC/L or more.

TABLE 5.2(a) SUMMARY OF TEST METHODS (BEAK LABS)

Tailings Solids

Total Digestion	o	Fusion of 0.25 g portion with lithium metaborate, dissolution in 5% nitric acid.
Water Leachate Metals	o	Leaching of 5 g portion with distilled deionized water until conductivity less than 50 umhos/cm.
Acid Leached Metals	o	Dilute nitric acid leach of residue after distilled deionized water leach.
DCP Analysis	o	Direct current plasma emission analysis of total digestion. For fractional analysis, water leach and dilute acid leach was used.
Sulphide	o	Total sulphur analysis of residue after dilute nitric acid leach or water leach, using a combustion sulphur analyzer
Sulphate	o	Turbidimetric or ion chromatographic analysis of distilled water or nitric acid leach. IC was used where DOC interferes.
Carbonate	o	Back titration after acid addition to solids.
CEC	o	Ammonia analysis after displacing exchanged ammonia from the material with, potassium, a more strongly adsorbed cation.

Pore Water

DCP Analysis	o	DCP analysis of an acidified sample as above
IC Scan	o	Dionex 10 ion chromatography with prefiltration
Ammonia	o	Nesslerization after distillation
Arsenic	o	Flameless hydride generation using sodium borohydride
Selenium	o	Flameless hydride generation using sodium borohydride
Reduced Sulphur	o	Turbidimetric sulphate analysis before and after oxidation of all reduced sulphur compounds to sulphate

TABLE 5.2(a) - (Cont'd) SUMMARY OF TEST METHODS (BEAK LABS)

Surface Water	
DCP Analysis	o DCP analysis of an acidified sample
Arsenic	o Flameless hydride generation using sodium borohydride
Selenium	o Flameless hydride generation using sodium borohydride
Boron	o Direct current plasma emission
IC Scan	o Dionex 10 ion chromatography
Suspended Solids	o Gravimetric after filtration (Whatman GF/C glass fiber) and desiccation at 105°C
Colour	o Direct comparison using Nessler tubes with Co-Pt Standard
Turbidity	o Direct readout using a Hach 2100 turbidimeter
Ammonia	o Nesslerization after distillation
Kjeldahl N	o Potassium sulphate and mercuric oxide micro kjeldahl digestion followed by Nesslerization of ammonia
O-Phosphate P	o colourimetric reaction with stannous chloride and ammonium molybdate or ion chromatography
Total Phosphate P	o Sulphuric acid and potassium persulphate digestion followed by stannous chloride and ammonium molybdate reaction
TOC	o Beckman 915A total organic carbon analyzer
TIC	o Beckman 915A total organic carbon analyzer (inorganic channel)
Vegetation	
Total Digestion	o In solution of nitric, sulphuric and perchloric acid
Water Leachate Metals	o As with tailings solids
Acid Leached Metals	o As with tailings solids
Arsenic	o As with pore water
Selenium	o As with pore water
DCP Analysis	o DCP analyses of acidified sample

Since most Lacnor samples had pH values less than 4, only an acidity titration is reported.

(ii) Anion Scan (PO_4^{3-}, NO_3^-, NO_2^-, Cl^-, SO_4^{2-}, F^-, Br^-)

The anions were determined by ion chromatogrphy on liquid samples using a Dionex model 10 system with the detection limits given in Table 5.1.

(iii) Carbonate - Solids

Carbonate was also determined indirectly using a titrimetric procedure. An accurately dispensed quantity of 0.01 N hydrochloric acid was added to a 15 g portion and the mixture was allowed to react for two hours with occasional stirring. During this process, carbonates were broken down and driven off as CO_2. The unreacted acid was then back-titrated with a standardized carbonate-free sodium hydroxide solution. The carbonate was then calculated from the amount of acid used up during the reaction. Due to the nature of the solids, no carbonates were detected (Allen et al, 1974; Section 23.9).

(iv) Cation Exchange Capacity - Solids

Cation exchange capacity was determined by washing a weighed portion of air-dried sample with a solution of ammonium acetate. The sample was then washed thoroughly with 57% ethanol and leached with a potassium chloride solution. The leachate was analyzed for ammonia by the automated phenate method. The cation exchange capacity is equal to the number of milliequivalents of ammonia leached from the ammonia acetate washed material. CEC was reported on a meq/100g basis. (Allen et al, 1974; Section 7.8).

(v) Loss on Ignition (LOI) - Solids

LOI was measured gravimetrically on a moisture free sample by ashing at 550°C to a constant weight.

(vi) Metals

(a) Metal Scan for Liquids: Direct Current Plasma (DCP) Analyser

Ag, Al, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Mo, Na, K, Pb, Ni, Ti, Sr, U, Zn, Si and B were determined by DCP. The DCP is a Beckman Spectraspan V Direct Current Plasma Analyser with a Spectrajet III DC argon plasma excitation source. It has two ten element cassettes for simultaneous determination of metals: one cassette for cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, silver, and zinc; and one cassette for aluminum, barium, beryllium, calcium, magnesium, molybdenum, potassium, sodium, strontium, and vanadium on the other cassette. A single element cassette was used for sequential determination of other single elements such as boron, thorium, silicon and titanium. A DBC-33 dynamic background compensator, a microprocessor controlled RS-232C data interface, an auto sampler interface, and a printer are ancillary pieces of equipment.

Instrument operation is not described in generally available documentation (e.g., APHA, 1983: EC, 1979). Reference is most readily made to the operational manuals, and accompanying literature.

(b) Selenium and Arsenic in Liquids: Atomic Absorption Spectrophotometer

A Perkin-Elmer Model 303 was used to measure selenium and arsenic by hydride generation using sodium borohydride. For selenium and arsenic interferences, the lower limits were enhanced by using high energy electrodeless discharge lamps. Occasionally, the known-addition technique was used to overcome interferences. Known standards were used to construct a calibration curve.

(c) Mercury in Liquid

A Perkin Elmer 403 spectrophotometer was used to analyze for mercury by cold vapour technique using stannous sulphate with a hollow cathode lamp. Known standards were used to construct a calibration curve.

(d) Porewater Samples - Total Metals

The porewater samples were analyzed for metals by DCP with the detection limits given in Table 5.1 upon field filtered, porewater samples.

(e) Surface Water Samples - Total Metals

Field acidified (HNO_3) samples were analyzed without further digesting by DCP after the addition of 100 ppm lithium as a chloride salt.

Special Analytical Procedures for Solids

Tailings Solids - Leachable Portion of Solids

The tailings solids were analyzed for heavy metals after two separate sequential leaching procedures. The first involved the leaching of a 5 g aliquot of sample material with distilled, demineralized water until the conductivity was below 50 umhos/cm. The sample was then leached with 30 ml of 1M HCl - 4M HNO_3 at 90°C for 2 hours. After cooling and centrifuging, the supernatant was decanted and made up to 50 ml. The leachate in each case was analyzed for metals by DCP.

Tailings Solids - Total Metals

The total heavy metals were determined by fusing a 0.25 g portion of dried, homogenized residue from the above leaching or original homogenized tailings material with lithium metaborate. The molten residue was dissolved in 5% nitric acid. Due to the dissolved solids content of the resultant solution, a minimum dilution factor of 20 was necessary. Cations were determined by DCP scan, as in liquid samples.

Vegetation Samples - Total Metal

Vegetation samples were first digested in a solution of nitric, sulphuric and perchloric acid to provide a liquid sample. All metals except arsenic (a metalloid) and selenium were analyzed by Beckman Spectraspan V Direct Coupled Plasma analyzer. Arsenic and selenium were analyzed by hydride generation atomic absorption spectroscopy.

Detection limits for the metals analyzed are provided in Table 4.2.6.

(vii) Moisture Content - Solids

Moisture content was determined gravimetrically by drying to constant weight at 105°C.

(viii) Nutrients

(a) Nitrogen Species

Nitrate and nitrite were determined by ion chromatography using a Dionex Model 10 system with detection limits given in Table 5.1. Because sulphate often interfered with their determination at the low concentrations, colorimetric methods were used at low levels.

Colorimetrically, nitrite was determined using the azo dye method (APHA, 1983, Section 419). Nitrate was determined colorimetrically by the brucine method (APHA 1971, Section 213C). For most samples, the sum of NO_3^- plus NO_2^- is reported.

Ammonia was determined by the automated phenate method without digestion. Total kjeldahl nitrogen (TKN) was determined by digestion with mercuric oxide, sulphuric acid and potassium persulphate (APHA, 1980 Section 420) to form ammonia and measurement of total ammonia in the sample by Nesslerization.

(b) Phosphorus

Soluble reactive phosphorus was determined by colour development using stannous chloride reduction (APHA, 1983 Section 424E). Orthophosphorus was determined by ion chromatography.

Total phosphorus was converted by digestion with sulphuric acid and potassium persulphate (APHA, 1983 Section 424C) to the soluble form whereupon an SRP determination was made.

(c) TOC, TIC

Total organic (TOC) and total inorganic (TIC) carbon were determined using a Beckman 915A Total Carbon Analyser and 865 Infrared Analyser. TOC involves stripping the inorganic carbon from the sample and measuring the CO_2 by IR after catalytic oxidation of the remaining organic carbon. TIC was determined as CO_2 by IR as well, after releasing the inorganic carbon on a bed of phosphoric acid coated quartz, at a lower temperature.

(ix) Physical Parameters on Liquid Samples

(a) Suspended and Dissolved Solids

Suspended solids were determined by filtering up to 200 ml of sample through a GF/C glass fibre filter and drying at 105°C to a constant weight. Dissolved solids were determined by drying a portion of the filtrate from suspended solids analysis at 105°C to a constant weight. Total solids were the sum of the above.

(b) Colour and Turbidity

Colour was determined by visual comparison to Co-Pt standards. Turbidity was determined by measuring the light scattered at right angles from a tungsten light source using a HACH 2100 turbidimeter.

(x) pH

pH measurement on liquid samples was made using an Orion pH meter calibrated with pH 4 and pH 7 standards, prior to reading the samples.

pH of soils and solids was measured by slurrying the solids sample with enough distilled water to allow immersion of electrodes. After fifteen minutes a reading was taken. (Allen et al, 1974; Section 4.4).

(xi) Sulphur

(a) Sulphur Species - Liquids

The methylene blue colour comparison method was used to determine sulphide (APHA, 1983 Section 427).

Sulphate was analyzed by IC or by wet methods. Reduced sulphur species were determined by oxidizing the sample with sodium carbonate, nitric and hydrochloric acids and analyzing the sample for sulphate, turbidimetrically (APHA, 1980; Section 420c). The difference between this sulphate level and that obtained without the digest represents the reduced sulphur concentration.

(b) Sulphur - Solids

Total sulphur and sulphide were determined directly using a Leco combustion technique. This technique uses combustion of the total sample in a stream of oxygen and integration of the evolved SO_2 by infrared detection for total sulphur. For sulphide a portion was leached with distilled water until the conductivity of the leach water was less than 50 umhos/cm. The latter procedure removes the sulphate present; the resulting total sulphur determination on the remaining residue yields sulphide sulphur. This method is valid under the assumption that there is no native sulphur or organically-bound sulphur present in the samples. The limit of detection obtainable by this method is 20 ppm as sulphur in both cases.

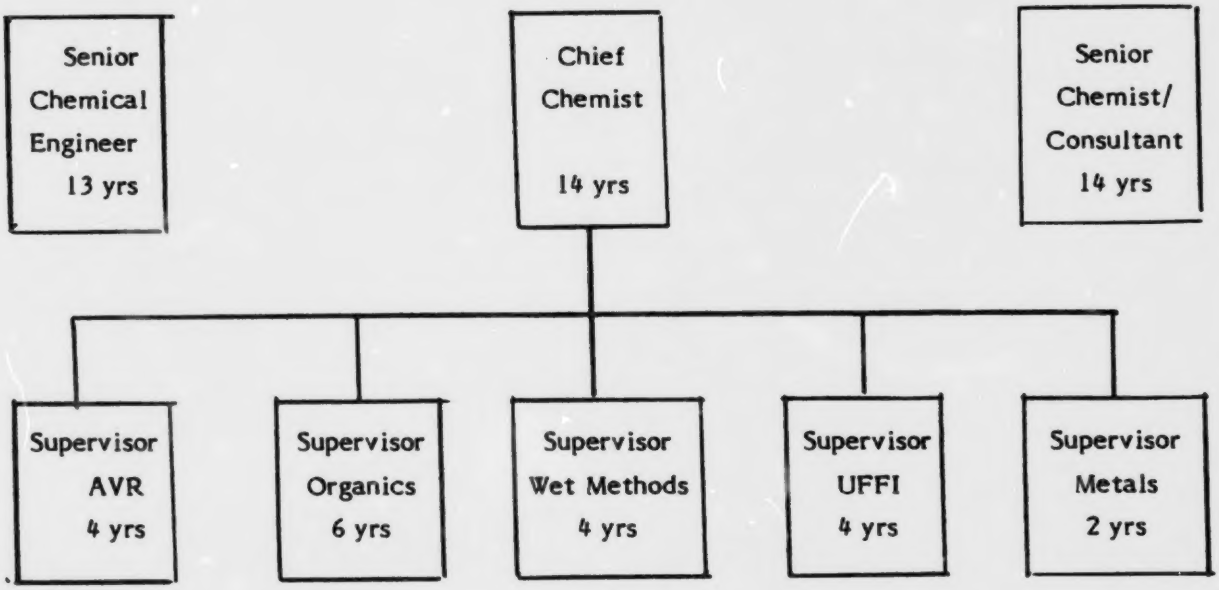
5.1.2 Quality Assurance Program (BEAK Laboratories)

The following quality assurance program was developed by BEAK to be cost effective yet sufficient to meet the needs of the specialized and varied workload encountered.

Principles

Production of quality data does not occur automatically and is not guaranteed by following any one or even several established procedures. Quality is achieved by dedicated effort, by careful attention to detail, and by practicing recognized principles

FIGURE 5.1 LABORATORY ORGANIZATION (BEAK)


Senior Chemical Engineer 13 yrs
Chief Chemist 14 yrs
Senior Chemist/ Consultant 14 yrs
Supervisor AVR 4 yrs
Supervisor Organics 6 yrs
Supervisor Wet Methods 4 yrs
Supervisor UFFI 4 yrs
Supervisor Metals 2 yrs

of quality assurance. These efforts are accompanied by a desire for excellence and professional pride which creates an atmosphere condusive to ensuring quality.

Sample Collection and Preservation

Any study requiring analytical tests to be carried out must address the collection of representative samples and the appropriate preservation of constituents for shipping. Standardization of the analytical techniques has been established to a high degree in our laboratory but the result of analysis is only as good as the sampling and sample preservation.

The following preservation techniques were recommended for:

- solid samples: keep cool;
- redox sensitive parameters: appropriate sampling and immediate measurement in a field laboratory;
- liquid samples;
- preserve metals samples in plastic bottles with 5 ml of 50% nitric acid per litre,
  - nutrients - preserve with 5 ml of 50% sulphuric acid per litre,
  - TIC/TOC - sample into an air tight bottle and keep cool,
  - anions - no preservative but keep cool.

Sample Handling and Storage

Samples arriving in the laboratory underwent inspection and documentation:

- the laboratory supervisor checked to make sure sampling instructions were followed,
- samples were identified and recorded on laboratory sheets (4 digit code) in the receiving area and transmittal documents were filed,
- samples were stored in a walk-in-cooler or in a freezer if required,
- the senior chemist or chief chemist inspected all difficult samples (heterogeneous mixtures, solids) and advised on subsampling/analytical verification procedures,
- samples were monitored for subsampling bias, and
- replicate samples were stored for future confirmation.

Laboratory Methods

Several analytical manuals/references were in routine use with analytical instrument operation manuals. The specific methods were described above. Special points include the following.

- each wet chemical parameter has its own binder with printed instruction, reporting tables, graphs and calculations,
- blank, standards, duplicates and reference solutions or reference materials were processed with each batch,
- spikes were processed occasionally with difficult samples,
- blind field duplicates were analyzed,
- method conditions were compared with past acceptable performance range from other projects,
- automated instruments, such as the DCP for metals, have special calibration and reporting procedures (e.g., selecting appropriate wavelengths for measuring a metal where the primary wavelength is interfered by another element),
- data were reviewed by the analyst and the supervisor to check for inconsistencies and precision and accuracy against references; questionable data was reanalyzed, and
- the senior chemist periodically reviewed implementation of QC, method performance and bias, accuracy, consistency and format.

Summary of Internal Quality Assurance Program Used in this Study

For solids, a reference standard (CANMET tailings UTS-1 to UTS-5 or appropriate standard) was analyzed for every twenty samples. For liquids, standard solutions for cations and anions of interest were analyzed every 15 to 20 samples. The DCP was calibrated daily. Electroneutrality balances were made on solutions where possible. An acceptable standard was judged to be ± 5% in concentrated waters and ± 10% in dilute systems, if analysis was done on the same bottle. If cations were analyzed on an acidified sample and anions on a filtered unpreserved sample, different criteria must be employed. Measured values of reference materials by BEAK are presented in Table 5.2b.

Table 5.2(b) MEASUREMENTS OF REFERENCE STANDARDS BY BEAK LABORATORIES FOR 1985 FOR NUTP MONITORING PROJECT

VII: EPA Reference 384, No. 7

	Value	June 1985	July 1985	Aug 1985	Measured Sept 1985	Oct 1985	Nov 1985	Dec 1985
Calcium	(40.6)	41	41	43/42/42	38/39	44	40	41/42
Magnesium	(8.4)	8.7	9.0	9.4/9.4/9.4	9.4/9.5	10.0	10.1	9.8/10.3
Potassium	(9.8)	9.8	9.9	10.5/10.3/10.0	10.9/10.2	10.6	10.8	10.6/10.5
Sodium	(46.5)	41	45	43/43/43	44/43	42	44	43/45

VIII: EPA Reference 581, No. 7

	Value	Measured July 1985	Sept 1985
Molybdenum	(1.70)	1.86	1.76
Calcium	(0.50)	0.66	0.49
Magnesium	(0.10)	0.22	0.08
Barium	(1.20)	1.29	1.17
Potassium	(0.20)	-	0.26
Sodium	(0.09)	-	-

IX: EPA Reference 581, No. 2

Value	Aug 1985	Measured Oct 1985	Nov 1985
(10.0)	10.7	10.5	10.8
(7.50)	7.6	6.8	7.0
(0.50)*	1.02	1.04	1.05
(10.0)	12	10	10
(1.50)	1.9	1.9	1.8
(1.50)**	3.1	3.3	2.5

X: ICAP Reference 1083, No. 7

	Value	Measured Dec 985
Aluminum	(0.97)	1.15/1.16
Barium	(0.97)	1.01/0.98
Potassium	(10.0)	11.3/11.4
Sodium	(0.86)	-/-

XI: EPA Reference 475, No. 6

	Value	Measured Jan 1985
Beryllium	(0.90)	0.84
Vanadium	(0.85)	0.62
Aluminum	(0.80)	0.52

XII: MBSS and BCSS References

	MESS Value	Feb 1985	BCSS Value	Feb 1985	June 1985
Zinc	(191)	187	(119)	113	130
Cadmium	(0.59)	2	(0.25)	L 2	-
Manganese	(513)	450	(229)	210	220
Cobalt	(10.8)	8	(11.4)	12	15
Copper	(25.1)	23	(18.5)	17	21
Iron	(30,500)	28,800	(32,900)	32,000	32,000
Lead	(34.0)	29	(22.7)	19	38
Chromium	(71)	65	(123)	119	132
Nickel	(29.5)	29	(55.3)	58	63

	MESS Value	Jan 1985	May 1985	BCSS Value	Jan 1985	Sept 1985
Aluminum	(58,400)	36,800	40,000	(62,600)	38,200	45,800
Beryllium	(1.9)	2	3	(1.3)	2	3
Molybdenum	(2.2)	L 2	-	(1.9)	L 2	-
Calcium	(4,820)	2,600	3,200	(5,430)	2,900	3,300
Vanadium	(72.4)	80	81	(93.4)	99	96
Magnesium	(8,680)	5,300	7,200	(14,720)	9,100	11,500
Barium	-	180	220	-	186	200
Potassium	(18,600)	13,600	19,800	(18,010)	13,400	13,900
Strontium	(89)	45	62	(96)	50	57
Sodium	(18,550)	15,000	18,300	(20,180)	16,100	16,800

5.2 Barringer Laboratories

Barringer Magenta Laboratories was the primary laboratory for analyses of non-radionuclide parameters for the Lacnor project for the following components:

- tailings solids,
- tailings porewater,
- surface water,
- atmospheric dust samples,
- biological and vegetation tissues
- high volume filters.

5.2.1 Laboratory Methods of Analysis (Barringer Laboratories)

The analytical methods described in this section are well established, published methods for the analysis of the parameters in question. They are very similar to the methods described in the following standard publications: APHA, (15th Edition, 1983); Environment Canada (1971); Rudolf Bock (1979); ASTM (1979); and Ontario Ministry of Environment (1984). A summary of the methods used and corresponding limits of detection are presented in Tables 5.3(a) and 5.3(b).

Tailings Solids - Leachable Portion of Solids

The tailings solids were analyzed for heavy metals after two separate leaching procedures. The first involved the washing of a suitable aliquot of sample material (ca. 10-20 g) with distilled, demineralized water. The sample was leached in a rotary agitator (MOE method for fill materials) and tumbled for a 24 hour period, and then filtered. The second procedure used dilute (.05N) sulphuric acid as the sequestering agent. The leachates in each case were analyzed for metals using Inductively-Coupled Argon Plasma Emission Spectroscopy (I.C.A.P) on an Applied Research Laboratories model QA-137 multi-channel plasma spectrophotometer. The solution detection limits are presented in Table 5.3(b); these represent the minimum detection levels observable in pure solution under ideal conditions. In order to attain the detection limits specified by the project, a maximum effective dilution factor of 10 from the leaching procedures was attempted.

TABLE 5.3(a) METHODS AND DETECTION LIMITS FOR REQUIRED CHEMICAL ANALYSES (BARRINGER)

Parameter	Solids		Waters	
	Detection Limit	Method	Detection Limit	Method
Metals	see Table 5.3b - ICAP			
$S^=$	20 ppm (as S)	Leco	-	-
$SO_4^=$	20 ppm (as S)	Leco	0.05 mg/L	I.C.
Reduced S	-	-	0.05 mg/L	I.C./H_2O_2
$CO_3^=$	1 ppm	Titrimetry	-	-
Cation Exch. Cap.	1 meq/100 mL	F.A.A.S.	-	-
F^-	-	-	0.005 mg/L	I.C.
Cl^-	-	-	0.01 mg/L	I.C.
$PO_4^=$	-	-	0.05 mg/L	I.C.
Br^-	-	-	0.05 mg/L	I.C.
NO_3^-	-	-	0.05 mg/L	I.C.
$SO_4^=$	-	-	0.05 mg/L	I.C.
Ortho-P	-	-	0.005 mg/L	Colourimetry
Total-P	-	-	0.005 mg/L	Colourimetry
NO_3^-	-	-	0.005 mg/L	Colourimetry
TKN	-	-	0.05 mg/L N	Colourimetry
NH_3	-	-	0.05 mg/L N	Colourimetry
As	-	-	0.001 mg/L	Hydride-A.A.
Se	-	-	0.001 mg/L	Hydride-A.A.
Colour	-	-	10 S.C.U.	Visual
Turbidity	-	-	10 N.T.U.	Fluorescence
T.D.S.	-	-	1 mg/L	Gravimetry
T.S.D.	-	-	1 mg/L	Gravimetry
T.O.C.	-	-	0.2 mg/L	IEC BEAK
T.I.C.	-	-	0.2 mg/L	IEC BEAK

TABLE 5.3(b) ANALYTICAL DETECTION LIMITS FOR I.C.A.P. METAL SCAN*

Element	Detection Limits	
	Waters (mg/L)**	Solids (ppm)***
Ag	0.005	0.1
Al	0.05	1
B	0.005	4
Ba	0.005	0.1
Be	0.0005	0.01
Ca	0.05	1
Cd	0.01	0.2
Co	0.05	1
Cr	0.01	0.2
Cu	0.01	0.2
Fe	0.01	0.2
K	1.0	20
Mg	0.01	0.2
Mn	0.01	0.2
Mo	0.2	4
Na	1.0	20
Ni	0.05	1
P	0.5	10
Pb	0.05	1
Si	0.05	50
Sr	0.001	0.02
Th	0.05	1
Ti	0.005	0.1
V	0.005	0.1
Zn	0.05	1
Zr	0.02	0.4

* Detection limit is for pure solution, not for matrix of samples analyzed in this study.

** If acid digestion is required, Si, Ba and B are not reported.

*** Based on $HF/HClO_4HNO_3$ digestion of sample.

Tailings Solids - Total Metals

The total heavy metals were determined by digesting a 0.25 g aliquot of dried, homogenized tailings material with a mixture of 7.5 ml hydrofluoric, 2.0 ml perchloric and 8.0 ml nitric acid ("concentrated", ACS grade acids). This was evaporated to dryness and the residue was redissolved in 10% hydrochloric acid. Due to the solids content of the resultant digestate, a minimum dilution factor of 20 was necessary. The only elements for which the detection limit requirements, specified by the project, were not met under this procedure were potassium (20 ppm), molybdenum (4 ppm) and barium (0.1 ppm). If K and Mo were near the detection limit, they were analyzed by flame atomic absorption, yielding detection limits of 0.2 ppm and 0.1 ppm, respectively. Barium is much more sensitive by I.C.A.P. than by flame A.A. where a detection limit of 0.1 ppm can be reliably obtained.

A separate procedure is involved for total silicon and boron. The sample is fused with a carbonate-based flux, a subsequent dissolution of the fusion mixture and then an analysis by I.C.A.P. The detection limit obtainable by this method is 50 ppm for Si and 4 ppm for B.

Tailings Solids - Sulphur Species

Sulphide and sulphate were determined indirectly using a Leco combustion technique which is based on the combustion of the sulphur in a stream of oxygen with subsequent determination of the evolved SO_2 by iodometric titration. The resulting sulphur determination yields total sulphur. The analysis was performed on an aliquot of the original sample and on an aliquot with hydrochloric acid. The HCl digestion procedure drives off the sulphide present as H_2S. The difference between these two analyses represents the sulphide content. This method is valid if there is no native sulphur or organically-bound sulphur present in the samples. The detection limit obtainable by this method is 20 ppm sulphur.

Tailings Solids - Carbonate

Carbonate was also determined on only a few samples, indirectly using a titrimetric procedure. A known quantity of 0.01 N hydrochloric acid was added to a 15 g aliquot and the mixture was allowed to react for two hours with occasional stirring to break down carbonates and drive off CO_2. The unreacted acid was back-titrated with a standardized carbonate-free sodium hydroxide solution. The carbonate was calculated from the amount of acid used up. A 1 ppm detection limit was attained by this method.

Tailings Solids - CEC

Cation exchange capacity was determined by washing a weighed aliquot of the sample with a solution of ammonium chloride. The sample was filtered and rinsed thoroughly with distilled, demineralized water. These rinsings were collected and the sodium, potassium, calcium and magnesium contents were measured. The cation exchange capacity is the sum of Na, K, Ca and Mg on a meg/100 ml basis.

Porewater - Metals

Porewater samples were analyzed for metals by ICAP. The detection limits have been given in Table 5.3(b). If copper was near the detection level, the samples were reanalyzed by flame atomic absorption to confirm the levels at a 0.005 mg/l detection level.

Arsenic and selenium were determined by heated quartz tube flameless atomic absorption following sodium borohydride-induced hydride formation. The detection limits from porewater tests are as shown in Table 5.3.

Porewater - Anions

The anions were determined by ion chromatography using a Dionex model 2110i system with the detection limits given in Table 5.3. The detection limits are based upon analysis of pure solutions. Samples were ordinarily diluted, in order to bring the sulphate into analytically measureable ranges.

Porewater - Nitrogen Species

Ammonia nitrogen was determined using an automated phenate colourimetric procedure. The detection limit is 0.05 mg/l as nitrogen.

Porewater - Reduced Sulphur

Reduced sulphur species were determined by oxidizing the sample with hydrogen peroxide and re-analyzing for sulphate by ion chromatography. The difference between this sulphate level and that obtained without the digestion is the oxidizable sulphur present in the sample.

Surface Water - Metals

The analytical procedures were identical to the ones described for porewater (above).

Surface Water - Nutrients

Total phosphorus and Kjeldahl nitrogen were determined colorimetrically (Ontario Ministry of the Environment, 1984). This procedure was generally used because orthophosphate was below the detection limit of ion chromatography. The sample was first acid digested. For TKN, a phenate colour development followed. For phosphorus and ascorbic acid, reduced antimony-tartarate colour development was used. Ammonia was determined by the phenate method without the digest. Nitrate was determined by the azo dye method following a cadmium reduction, in a few spot samples.

Surface Water - TOC/TIC

Total organic and inorganic carbon was determined using the Beckman I.R. technique, and was subcontracted to Beak Analytical Serices.

Surface Water - Physical Parameters

The determination of solids involved filtering a 200 ml sample through a 0.45 um membrane filter. The filtrate was evaporated and dried to constant weight. The residue was weighed to determine the dissolved solids content. An unfiltered sample was evaporated and dried and the residue weighed to give the total solids content. The difference represents the suspended solids concentration.

TABLE 5.4a: BARRINGER METAL SCAN QA (Ag to Cr) +

Report Date	Sample I.D.	Ag (ppm)	Al (ppm)	B (ppm)	Ba (ppm)	Be (ppm)	Ca (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)
21 May 85	ERA STD	L 0.005	0.18	0.200	0.219	0.0492	L 0.01	0.05	0.15	0.07
	ERA STD	L 0.005	0.19	0.195	0.231	0.0488	0.03	0.04	0.14	0.07
	Certified Value	-	0.20	-	-	0.053	-	0.04	0.16	0.07
06 Jun 85	ERA STD	L 0.005	0.18	0.181	0.146	0.0475	L 0.01	0.04	0.16	0.07
	ERA STD	0.017	0.17	0.172	0.169	0.0465	0.04	0.05	0.16	0.07
	SWO2UAPR22	L 0.005	10.2	L 0.004	0.011	0.0007	120	0.01	0.12	0.03
	ERA STD	L 0.005	0.16	0.176	0.189	0.0481	0.01	0.05	0.14	0.07
	SWO1UMAY7	L 0.05	36.9	L 0.04	L 0.05	L 0.005	255	L 0.1	L 0.5	L 0.1
	SWO2FMAY6	L 0.05	9.8	L 0.04	L 0.05	L 0.005	105	L 0.1	L 0.5	L 0.1
	SWO1UMAY9	0.14	32.9	L 0.04	L 0.05	L 0.005	254	L 0.1	L 0.5	L 0.1
	SWO2UMAY9	L 0.05	10.6	L 0.04	L 0.05	L 0.005	119	L 0.1	L 0.5	L 0.1
	SWO2UAPR22	0.18	9.6	L 0.04	L 0.05	L 0.005	108	L 0.1	L 0.5	L 0.1
	SWO1UMAY22	0.12	31.5	L 0.04	L 0.05	0.005	315	L 0.1	L 0.5	0.1
	SWO1UMAY13	0.05	32.9	L 0.04	L 0.05	L 0.005	275	L 0.1	L 0.5	0.1
	SWO1UMAY6	L 0.05	30.5	L 0.04	L 0.05	L 0.005	231	L 0.1	L 0.5	L 0.1
	SWO2UMAY30	0.13	13.9	L 0.04	L 0.05	L 0.005	181	L 0.1	L 0.5	L 0.1
	SWO1UMAY30	0.06	29.2	L 0.04	L 0.05	L 0.005	293	L 0.1	L 0.5	L 0.1
	SWO2UMAY15	L 0.05	11.9	L 0.04	L 0.05	L 0.005	137	L 0.1	L 0.5	L 0.1
	SWO2UMAY22	L 0.05	13.0	L 0.04	L 0.05	L 0.005	159	L 0.1	L 0.5	L 0.1
08 Aug 85	SW-03-JUL.11	L 0.005	9.10	L 0.004	0.028	0.0006	49.3	L 0.01	0.10	0.02
	ERA STD	L 0.005	0.25	0.183	0.198	0.0488	L 0.01	0.04	0.15	0.07
12 Dec 85	EPA TRACE 2	L 0.005	0.80	L 0.004	0.014	0.235	L 0.01	0.04	0.33	0.28
	W-POND-AUG1	L 0.005	24.4	L 0.004	L 0.005	0.0026	290	0.01	0.34	0.15
	W-POND-AUG1	L 0.005	25.5	L 0.004	L 0.005	0.0027	290	0.01	0.32	0.13
	EPA TRACE 2	L 0.005	0.81	0.012	0.014	0.237	L 0.01	0.04	0.32	0.28
	Certified Value	-	0.73	-	-	0.235	-	0.039	0.26	0.26
04 Oct 85	BLANK	L 0.3	3.9	L 0.2	L 0.3	L 0.02	15.1	L 0.5	L 3	L 0.5
	L-20	L 0.3	112	3.4	16.5	L 0.02	2,670	L 0.5	L 3	L 0.5
	L-20	L 0.3	116	3.0	15.8	L 0.02	2,670	L 0.5	L 3	0.6
	CITRUS LEAF	L 0.3	32.1	27.0	16.3	0.03	29,600	L 0.5	L 3	1.9
	Certified Value	-	92	-	21	-	31,500	0.03	0.02	0.8

TABLE 5.4b: BARRINGER METAL SCAN QA (Cu to Pb) +

Report Date	Sample I.D.	Cu (ppm)	Fe (ppm)	K (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)
21 May 85	ERA STD	0.113	0.20	L 1	L 0.01	0.07	0.3	L 1	0.21	L 0.5	
	ERA STD	0.112	0.22	L 1	L 0.01	0.07	0.3	L 1	0.20	L 0.5	
	Certified Value	0.117	0.21	-	-	0.08	0.3	-	0.22	-	
06 Jun 85	ERA STD	0.115	0.20	L 1	L 0.01	0.07	0.3	L 1	0.21	L 0.5	
	ERA STD	0.111	0.20	L 1	L 0.01	0.07	0.3	L 1	0.23	L 0.5	
	SWO2UAPR22	0.056	281	8	34.1	2.63	L 0.2	8	0.13	L 0.5	
	ERA STD	0.116	0.20	L 1	L 0.01	0.07	0.2	L 1	0.20	L 0.5	
	SWO1UMAY7	0.18	266	L 10	27.5	1.2	L 2	L 10	L 0.5	L 5	
	SWO2FMAY6	L 0.08	167	L 10	24.2	1.7	L 2	L 10	L 0.5	L 5	
	SWO1UMAY9	0.17	267	L 10	25.9	1.2	L 2	L 10	0.5	L 5	
	SWO2UMAY9	L 0.08	180	L 10	25.8	1.8	L 2	L 10	L 0.5	L 5	
	SWO2UAPR22	L 0.08	269	L 10	32.3	2.4	L 2	L 10	L 0.5	L 5	
	SWO1UMAY22	0.13	334	L 10	30.9	1.4	L 2	L 10	L 0.5	L 5	
	SWO1UMAY13	0.10	288	L 10	27.9	1.2	L 2	L 10	L 0.5	L 5	
	SWO1UMAY6	0.12	226	L 10	23.6	1.1	L 2	L 10	L 0.5	L 5	
	SWO2UMAY30	L 0.08	338	20	44.1	3.2	L 2	10	L 0.5	L 5	
	SWO1UMAY30	0.12	303	L 10	28.6	1.3	L 2	L 10	L 0.5	L 5	
	SWO2UMAY15	L 0.08	212	L 10	31.1	2.1	L 2	L 10	L 0.5	L 5	
	SWO2UMAY22	L 0.08	272	L 10	38.3	2.7	L 2	L 10	L 0.5	L 5	
08 Aug 85	SW-03-JUL.11	0.032	21.4	2	11.8	0.81	L 0.2	3	0.10	L 0.5	
	ERA STD	0.113	0.17	L 1	L 0.01	0.07	0.2	L 1	0.23	L 0.5	
12 Dec 85	EPA TRACE 2	0.331	0.79	L 1	0.01	0.33	L 0.2	1	0.21	L 0.5	
	W-POND-AUG1	0.118	132	12	72.5	3.41	0.5	15	0.21	L 0.5	L 0.05
	W-POND-AUG1	0.116	136	11	73.9	3.41	0.4	16	0.20	L 0.5	L 0.05
	EPA TRACE 2	0.336	0.77	1	L 0.01	0.34	L 0.2	1	0.21	L 0.5	0.44
	Certified Value	0.339	-	-	-	0.348	-	-	0.207	-	0.435
04 Oct 85	BLANK	L 0.4	1.9	L 50	6.7	L 0.5	L 10	L 50	L 3	L 30	
	L-20	15.6	336	9,420	1,470	183	L 10	L 50	3	1,380	
	L-20	13.4	345	7,440	1,490	192	L 10	L 50	3	1,360	
	CITRUS LEAF	13.9	69.9	16,600	5,540	17.2	10	150	5	1,160	
	Certified Value	16.5	90	18,200	5,800	23	0.17	160	0.6	1,300	

TABLE 5.4c: BARRINGER METAL SCAN QA (Si to Zr) +

Report Date	Sample I.D.	Si (ppm)	Sr (ppm)	Th (ppm)	Ti (ppm)	V (ppm)	Zn (ppm)	Zr (ppm)
02 May 85	ERA STD	0.37	L 0.001	0.06	0.214	0.303	0.25	L 0.05
	ERA STD	0.36	L 0.001	L 0.05	0.215	0.293	0.24	L 0.05
	Certified Value	-	-	-	0.228	0.317	0.25	-
06 Jun 85	ERA STD	0.08	L 0.001	L 0.05	0.215	0.324	0.26	L 0.05
	ERA STD	0.07	L 0.001	L 0.05	0.208	0.329	0.27	L 0.05
	SWO2UAPR22	12.5	0.191	0.11	0.017	0.026	0.11	0.08
	ERA STD	0.07	L 0.001	L 0.05	0.220	0.328	0.27	L 0.05
	SWO1UMAY7	22.9	0.25	L 0.5	0.07	L 0.05	L 0.5	L 0.5
	SWO2FMAY6	8.8	0.15	L 0.5	L 0.05	L 0.05	L 0.5	L 0.5
	SWO1UMAY9	21.9	0.25	0.6	0.08	0.10	L 0.5	L 0.5
	SWO2UMAY9	9.6	0.16	L 0.5	L 0.05	L 0.05	L 0.5	L 0.5
	SWO2UAPR22	10.8	0.20	L 0.5	L 0.05	0.06	L 0.5	L 0.5
	SWO1UMAY22	24.8	0.30	0.7	0.08	L 0.05	L 0.5	L 0.5
	SWO1UMAY13	23.8	0.26	L 0.5	L 0.05	L 0.05	L 0.5	L 0.5
	SWO1UMAY6	21.0	0.22	0.6	L 0.05	L 0.05	L 0.5	L 0.5
	SWO2UMAY30	14.0	0.25	0.9	0.06	L 0.05	L 0.5	L 0.5
	SWO1UMAY30	22.0	0.26	0.8	0.06	L 0.05	L 0.5	L 0.5
	SWO2UMAY15	11.1	0.17	L 0.5	L 0.05	L 0.05	L 0.5	L 0.5
	SWO2UMAY22	12.8	0.23	L 0.5	L 0.05	L 0.05	L 0.5	L 0.5
08 Aug 85	SW-03-JUL.11	9.19	0.072	0.07	L 0.005	0.007	0.11	L 0.05
	ERA STD	0.45	L 0.001	L 0.05	0.224	0.324	0.25	L 0.05
12 Dec 85	EPA TRACE 2	0.17	L 0.001	0.05	L 0.005	0.883	0.45	L 0.05
	W-POND-AUG1	21.2	0.353	0.39	L 0.005	L 0.005	0.13	0.09
	W-POND-AUG1	19.9	0.378	0.36	L 0.005	L 0.005	0.13	0.09
	EPA TRACE 2	0.18	L 0.001	0.08	L 0.005	0.906	0.46	L 0.05
	Certified Value	-	-	-	-	0.846	0.418	-
04 Oct 85	BLANK	12	L 0.05	L 3	0.4	L 0.3	L 3	L 3
	L-20	377	2.93	4	5.4	0.4	14	L 3
	L-20	233	2.96	4	4.8	0.5	13	L 3
	CITRUS LEAF	110	93.1	13	4.1	L 0.3	24	L 3
	Certified Value	-	100	-	-	-	29	-

TABLE 5.4d: BARRINGER QA FOR ANIONS IN SURFACE WATERS AND As, Se and Pb IN SOILS +

Lab I.D.	Sample I.D.	F (mg/L)	Cl (mg/L)	NO_2 (mg/L)	PO_4 (mg/L)	Br (mg/L)	NO_3 (mg/L)	SO_4 (mg/L) (S4)	As (ug/L) (S5)	Se (ug/L)	NH_3-N (mg/L)	$SO_4^=$ (mg/L)	$SO_4^=$ (mg/L)
	Surface Water												
328	GW-02/I	3.70	11.0	L 2	L 10	L 10	L 5	6,650	20	L 1	3.6	12,700	5,840
	GW-02/I Repeat	3.90	13.0	L 2	L 10	L 10	L 5	6,490	21	L 1	3.5	13,200	4,980
	GW-05/I	3.10	26.0	L 2	L 10	L 10	L 5	4,570	4	L 1	4.6	11,400	4,520
	GW-05/I Repeat	3.90	28.0	L 2	L 10	L 10	L 5	4,510	4	L 1	4.4	-	-
546	GW-03-G	3.24	117	L 0.2	L 1	L 0.5	L 5	3,320	-	L 1	3.81	3,360	-
	GW-03-G Repeat	3.18	117	L 0.2	L 1	1.0	L 5	3,270	-	L 1	4.01	3,270	-
	GW-04-A								L 1				
	GW-04-A Repeat								L 1				

+ FOOTNOTE FOR TABLE 5.4a to 5.4d: EXPLANATION OF SAMPLE I.D.

- ERA STD: Measured value by Barringer of Environmental Resource Associates reference sample.

- Certified Value: "Known" value of ERA STD or EPA standard. Certified value is inserted below appropriate standard only once in table.

- For 06 Jun 85 and 08 Aug 85, sample I.D. (e.g., SW02UAPR22) are duplicate values measured by Barringer as a part of their internal laboratory QA. The reported value is given in the Tables in Appendix 3.

- For 12 Dec 85 samples, reported value and internal laboratory duplicated are both reported.

- For 04 Oct 85 sample, measurement of the reagent blank, digested vegetation sample L-20, and digested citrus leaf reference standard are reported.

TABLE 5.4e: ADDITIONAL BARRINGER QA FOR IC SCAN AND NUTRIENTS⁺

Lab I.D.	Sample I.D.	As (ug/L)	Se (ug/L)	F^- (mg/L)	Cl^- (mg/L)	NO_2^- (mg/L)	$PO_4^=$ (mg/L)	Br^- (mg/L)	NO_3^- (mg/L)	$SO_4^=$ (mg/L)	Cond. (umhos/cm)	TDS (mg/L)	TKN (mg/L)	Total P (ug/L)
	Surface Water													
814	LA-SW-01-Aug 29			3.22	5.60	L 0.02	L 0.1	L 5	L 5	2,070				
	LA-SW-01-Repeat			2.93	5.29	L 0.02	L 0.1	L 5	L 5	2,010				
496	LA-SW-01-Jul 25			0.90	2.08	L 0.2	L 1	L 0.5	1.0	2,030				
	LA-SW-01-Repeat			0.85	2.05	L 0.2	L 1	L 0.5	L 0.5	2,010				
302	LA-SW-01-May 9			0.65	1.48	L 0.02	L 0.1	L 0.1	L 1	1,480				
	LA-SW-01-Repeat			0.67	1.59	L 0.02	L 0.1	L 0.1	L 1	1,480				
227	SW-01 UN 29/4			0.98	2.49	L 0.02	L 0.1	L 0.1	L 1	1,350	4,100	-	1.90	11
	Repeat			0.99	2.24	L 0.02	L 0.1	L 0.1	L 1	1,430	4,190	-	1.80	9
	SW-01 25/4											52		
	Repeat											61		
	SW-02 26/4	L 1	L 1											
	Repeat	L 1	L 1											
	SW-01 Apr 18												0.69	10
	Repeat												0.68	6
	EPA Min 2	-	-	0.44	17.6	-	-	-	-	7.09	112	-	-	-
	Certified Value	-	-	0.43	17.8	-	-	-	-	7.2	108	-	-	-
	EPA Nut. Silver												7.0	2,700
	Certified Value												7.1	2,700
	EPA Trace Conc. 13		7.3											
	Certified Value		(7.6)*											
	EPA Trace Metal 1													
	Conc. 2	218												
	Certified Value	(235)*												

* ( ) indicates known values.

⁺ Value reported in data tables and the repeat measured as part of Barringer internal QA are given here together (e.g., LA-SW-01-Repeat is the repeat of LA-SW-01-Aug 29 reported in Appendix 3).

TABLE 5.4f: ADDITIONAL BARRINGER QA FOR VEGETATION AND SOIL ANALYSIS (W.O. 85-06-3)

	As (ppm)	Se (ppm)	Pb (ppm)
Vegetation			
L20	0.23	0.50	L 3
L20 Repeat	0.23	0.44	L 3
Citrus Leaf (analysis)	2.5	0.03	10
Citrus Leaf Certified	(3.1)*	(0.025)*	(13.3)*
Blank	L 0.01	L 0.01	L 3
Soil			
L27	3.72	0.54	135
L27 Repeat	3.86	0.50	130
NBS1646	9.62	0.48	30
Certified	(11.6)*	(0.60)*	(28.2)*
Blank	L 0.1		

* ( ) indicates known values.

Colour was determined by visual comparison to Co-Pt standards and turbidity was measured by light scattering.

Vegetation - Metals

Samples are first extracted by digestion in a solution of nitric, sulphuric and perchloric acid. All metals except arsenic, selenium and lead were analyzed by Inductively Coupled Argon Plasma (ICAP) scan. Detection limits for this method are presented in Table 5.3. Arsenic and selenium were analyzed by Hydride Generation Atomic Absorption Spectroscopy (detection limits 0.020 mg/L) and lead by atomic absorption spectroscopy (detection limits 0.05 mg/L).

5.2.2 Quality Assurance/Quality Control Program (Barringer Laboratories)

Summary of Program

Samples which enter the laboratory were logged in a centralized filling system and issued a work order number prior to being forwarded to the appropriate laboratory section. An updated work order log was maintained on a computer system for quick reference. All laboratory staff kept records of all work in personal laboratory notebooks.

Routine quality control practice involved the analysis of one control sample for every 10 to 15 samples analyzed. The control sample was either a reagent blank, sample replicate or a certified reference material (if available). The reagent blank was used to monitor any possible sources of contamination in the reagents or glassware used or inherent in the method used. The analysis of sample replicates gave an indication of the analytical precision and/or the sample homogeneity. The reference material was employed primarily as an accuracy control but it could also provide a check on analytical precision and recoveries. If the sample replicate showed larger deviations than expected, and if a sufficient number of replicates of the reference material were included in the batch, the results could be used to determine the analytical precision of the technique. Because reference materials should, by design, be more homogenous than actual samples, sample imprecision may simply reflect inhomogeneity, caused by inadequate preparation procedures or an insufficient aliquot of the sample being measured.

In this project, the reference materials used are presented in Table 5.4.

The solid samples were analyzed along with a series of reference materials which are deemed most appropriate for the particular type of matrix. Reference materials for the solids analyses were chosen to match the sample matrices as closely as possible. The tailings solids were matched by using reference uranium tailings, UTS-1 through to UTS-4. These have been analyzed previously by Barringer for metals (ICAP and AAS, Th, U, S and $SO_4^=$). In addition, other uranium ores and rock standards were also available for use.

Laboratory Performance Evaluation

Barringer participated in a wide variety of Interlaboratory comparison programs. Relevant programs include the US EPA; Environment Canada and the CANMET Certified Reference Material Program.

5.2.3 Results of QA/QC Program (Barringer)

Results of the QA/QC Program of Barringer are given in Table 5.4. An explanation of the sample ID is given in the footnote.

5.3 Monenco Laboratories, Calgary, Alberta

For the Lacnor program, Monenco conducted the following analyses:

- Tailings solids - check samples analyzed by Monenco
- Tailings porewater - Check samples only
- Surface water - Major laboratory for analysis
- Hi Vol Filters - Check samples only analyzed
- Biological and vegetation tissues - three vegetation samples analyzed.

5.3.1 Summary of Analytical Methods (Monenco)

Sample Preservation and Preparation

Liquids: Water samples for dissolved radionuclide analysis were assumed to have been field-filtered and preserved prior to shipment to the laboratory. Any water samples for total radionuclide analysis were also acidified in the field; they were subsequently digested in the laboratory prior to analysis.

Solids: Solids were dried at 50°C and ground to ensure sample homogeneity. Prior to drying the moisture content was measured. Solid samples were dissolved by KF-pyrosulfate fusion for the determination of radium and thorium and by digestion using a hot concentrated mixture of nitric, perchloric and hydrofluoric acids, followed by a pyrosulfate fusion for the determination of lead and polonium. Subsamples for radionuclide analysis exceeded 0.5 gms in order to minimize uncertainty due to the counting statistics.

Hi Vol Filters: Samples decomposition was conducted using $HF/HClO_4/HNO_3$ digestion followed by pyrosulfate fusion. The sample was made up to a standard volume in a volumetric flask and then aliquots taken for various determinations by the methods listed in Section 5.3.

Vegetation: Similar techniques to those for solids were employed for vegetation.

Summary of Analytical Methods

All samples were analyzed according to the procedures outlined in the "Analytical Methods Manual-National Uranium Tailings Program" by Dean and Chiu, 1984. They are in summary:

Radium-226, Radium-223 - High Resolution Alpha Spectrometry
(HRAS) (Ba-133 Tracer).

Th-232, Th-230, Th-228 - HRAS (Th-234 tracer).

Radium-228 - indirect measurement of daughter, Actinium 228, a beta emitter.

Lead-210 - indirect measurement of daughter, bismuth-210, a beta emitter.

Polonium-210 - HRAS (Po-208 tracer).

Uranium - delayed neutron activation (solids), fluorimetry (liquids).
Uranium Ratio
(U-234, U-234, U-238) - HRAS (after isolation of uranium).

Specific Analytical Procedures

Pb-210

Summary: Indirect measurement of daughter, bismuth-210.

Method: One must allow 30 days for the ingrowth of Bi-210, a beta emitter, to achieve an equilibrium of greater than 98%. A carrier solution of stable lead and bismuth was added prior to digestion. Bismuth was then solvent-extracted, subsequently precipitated as bismuth oxychloride and beta-counted to measure Bi-210, the first daughter of Pb-210. The absolute detection limit for Pb-210 was 0.05 Bq. (Dean and Chiu, 1984).

Po-210

Summary: Polonium-210 - HRAS (Po-208 Tracer).

Method: A tracer solution of Po-208 was added prior to digestion. The polonium isotopes were deposited on a nickel disc and determined by alpha spectroscopy. The overall chemical yield was determined by the recovery factor Po-208. The detection limit for Po-210 was 0.01 Bq.

Ra-226

Summary: Radium-226, Radium-223 - High Resolution Alpha Spectrometry (HRAS) (BA-133 Tracer).

Method: A tracer solution of Ba-133 was added prior to digestion. Radium was coprecipitated with $PbSO_4$, subsequently dissolved and isolated by co-precipitation with $BaSO_4$. The overall chemical yield was determined by gamma counting of Ba-133; Ra-226 was then determined by alpha spectroscopy. The detection limit for Ra-226 was 0.01 Bq. (Dean and Chiu, 1984).

Ra-228

Summary: Indirect measurement of daughter, Actinium-228, a beta emitter.

Method: Radium-228 and other radium isotopes were separated by co-precipitation with lead sulphate, re-dissolved and purified by co-precipitation with barium sulphate. The barium (radium) sulphate was stored to allow the ingrowth of Ac-228, the first daughter of Ra-228 and known to grow into equilibrium with Ra-228 by virture of its short half life. Actinium-228 was then separated from the radium isotopes by co-precipitation with cerous hydroxide which was then beta-counted to a detection limit of 0.05 Bq. (Dean and Chiu, 1984).

Ra-223

Summary: High Resolution Alpha Spectrometry (HRAS, BA-133 Tracer).

Method: Radium isotopes were collected as described for Ra-226 and determined by alpha spectroscopy. While the alpha energy of Ra-226 was clearly separate from Ra-223 and Ra-224, the alpha energies of these latter two isotopes (5.71 and 5.68 MeV respectively) are too close to permit resolution. In the natural environment, Ra-224 was not expected to be present in significant amounts but it was found to occur in waste tailings streams in other NUTP projects. In such cases, its presence affected the precision of the Ra-223 measurement. The Ra-224 contribution, if any, was quantified and subtracted by measurement of its daughter products Bi-212 and Po-212 by alpha counting techniques. The detection limit of Ra-223 was 0.05 Bq. Dean and Chiu, (1984).

Th-232, Th-230, Th-228

Summary: HRAS (Th-234 tracer)

Methods: A tracer solution of Th-234 was added prior to digestion. Thorium was coprecipitated with $PbSO_4$, isolated by solvent extraction, and then coprecipitated with cerous hydroxide. The thorium precipitate was then beta-counted for Th-234 to measure the overall yield and then Th-230, Th-232 and Th-228 were determined by alpha spectroscopy. The detection limit for Th-230, Th-232, and Th-228 was 0.01 Bq. Dean and Chiu, 1984.

Uranium - Total

Summary: Fluorimetry (liquids)/delayed neutron activation (solids).

Method: In liquid samples, natural uranium was determined fluorimetrically as its fluoride complex following fusion with sodium fluoride-lithium fluoride. In solid samples, U was determined by DNA. The detection limit for uranium was 0.1 ug. (Dean and Chiu, 1984).

Uranium Ratio

Summary: Uranium Ratio (U-234/U-238:HRAS after isolation of uranium.

Method: Uranium was chemically separated from a water sample by co-precipitation with aluminum phosphate, solvent extraction and co-precipitated with cerous fluoride. U-238, U-234, and U-235 (if required) were determined by alpha spectroscopy. (Dean and Chiu, 1984; Sill and Williams 1981).

Detection Limits

Detection limits for various radionuclides are given in Table 5.5. The mass of each isotope measured is so small that one does not have a "normal operating range" or a "bias" (versus true value), such as one would encounter for chemical methods of analysis for cations and anions (see Table 5.1). Accordingly, the routine analytical operating range is not given because it is not meaningful.

5.3.2 Quality Assurance and Quality Control Program (Monenco)

Quality Assurance Program

The quality assurance program for radiochemistry of solids involved the analysis of one or two CANMET reference materials (UTS-1 to UTS-5) or reference ore (e.g., DL-1, DL-2, etc.) for every 15-20 field samples analyzed. For liquids, one reference solution is used for up to 10 samples in a batch for Ra-226, Th isotopes, and Po-210. Two reference solutions are used for up to 10 samples for Ra-228 and Po210 determinations. In addition, the alpha spectrometers, gamma spectrometers and beta spectrometers were calibrated daily.

One replicate analysis per batch of 15-20 samples was made. A tracer was added to every sample, reference solution, or certified reference to check recovery.

TABLE 5.5a: OPERATING CHARACTERISTICS OF RADIONUCLIDE ANALYSIS FOR WATER (Routine Procedure)

Parameter	Unit of Measurement	Best Method Lowest Reported Value*
Total U	ug/L (ppb)	0.5
U-238	not applicable	-
U-234	(activity ratio measured)	-
Th-230	Bq/L	0.005
Ra-226	Bq/L	0.005
Pb-210	Bq/L	0.1
Po-210	Bq/L	0.005
Th-232	Bq/L	0.005
Ra-228	Bq/L	0.1
Th-228	Bq/L	0.005

* Assuming 1 litre sample size.

TABLE 5.5b: OPERATING CHARACTERISTICS OF RADIONUCLIDE ANALYSIS FOR SOLIDS (Routine Procedure)

Parameter	Unit of Measurement	Best Method Lowest Reported Value*
Total U	ug/g	0.5
U-238	(activity ratio measured)	-
U-234	(activity ratio measured)	-
Th-230	Bq/g	0.005
Ra-226	Bq/g	0.005
Pb-210	Bq/g	0.1
Po-210	Bq/g	0.005
Th-232	Bq/g	0.005
Ra-228	Bq/g	0.1
Th-228	Bq/g	0.005

* Assuming 1 gm sample size.

TABLE 5.5c: OPERATING CHARACTERISTICS OF RADIONUCLIDE ANALYSIS FOR SEDIMENT (Routine Procedure)

Parameter	Unit of Measurement	Best Method Lowest Reported Value*
Total U	ug/g (ppb)	0.5
U-238	not applicable	-
U-234	not applicable	-
Th-230	Bq/g	0.005
Ra-226	Bq/g	0.005
Pb-210	Bq/g	0.10
Po-210	Bq/g	0.005
Th-232	Bq/g	0.005
Ra-228	Bq/g	0.10
Th-228	Bq/g	0.005

* Assuming 1 gm sample size.

TABLE 5.5d: OPERATING CHARACTERISTICS OF RADIONUCLIDE ANALYSIS FOR FISH (Routine Procedure)

Parameter	Unit of Measurement	Best Method Lowest Reported Value*
Total U	ug/kg tissue	10
U-238	-	-
U-234	-	-
Th-230	Bq/kg	5
Ra-226	Bq/kg	5
Pb-210	Bq/kg	0100
Po-210	Bq/kg	5
Th-232	Bq/kg	5
Ra-228	Bq/kg	100
Th-228	Bq/kg	5

* Depends on sample size available and method of sample dissolution, i.e., whether dry ashed or wet digested. These numbers assume 1.0 gm wet weight digested, and used for analysis of one individual isotope.

Laboratory Quality Control Program

The quality control program which attempts to assure the scientific reliability of the laboratory data, used management, administrative, statistical, investigative, preventive and corrective techniques to maximize reliability of the data.

It involved:

- the publication and distribution of current and complete analytical methods and procedures and analytical instrument operating instructions;
- the distribution and retention of laboratory reports with provision for administrative technical review;
- Quality control checks on analytical instruments to ensure proper function at all times;
- a Preventive Maintainence Program; and
- an analytical quality control system to ensure continued precision and accuracy of laboratory results. This includes:

  a) daily instrument calibration with standards,
  b) where available, control samples included with each run. A control sample is one that has a similar matrix and has a working value established by organizations such as ASTM or APHA,
  c) when a control sample is not available, a previously run unknown is included as a blind check sample,
  d) a reagent blank is analyzed for all parameter determinations,
  e) if the results attained for the control or recycle samples are not within acceptable limits, the entire batch of analyses are repeated and control verified before reports are issued,
  f) policy (e) is based on the presence of large enough samples. When such is not the case two options are available:
    (i) non-acceptance of the analysis by the laboratory, or
    (ii) waiving of the quality control actions by the client.
- Participation in inter-laboratory quality evaluation programs.
- All personnel trained and qualified in quality control techniques prior to running new analyses.

Organization of Laboratory Quality Control Progam

Figure 5.2 shows the organization of the quality control program. The quality control coordinator reports to the lab manager. Each section has its own quality control program and is under the administration of the coordinator.

Duties of Coordinator

- Responsiblity of Q.C. program and for taking or recommending Q.C. measures to ensure accuracy and precision of data produced.
- Develops statistical prcedures and techniques and supervises their use.
- Seeks out and evaluates new ideas in Q.C.
- Monitors Q.C. program.
- Advises lab manager in reviewing technology methods and equipment with respect to Q.C. aspects.
- Recommends laboratory safety and occupational hygiene measures.

Duties of Q.C. Supervisor

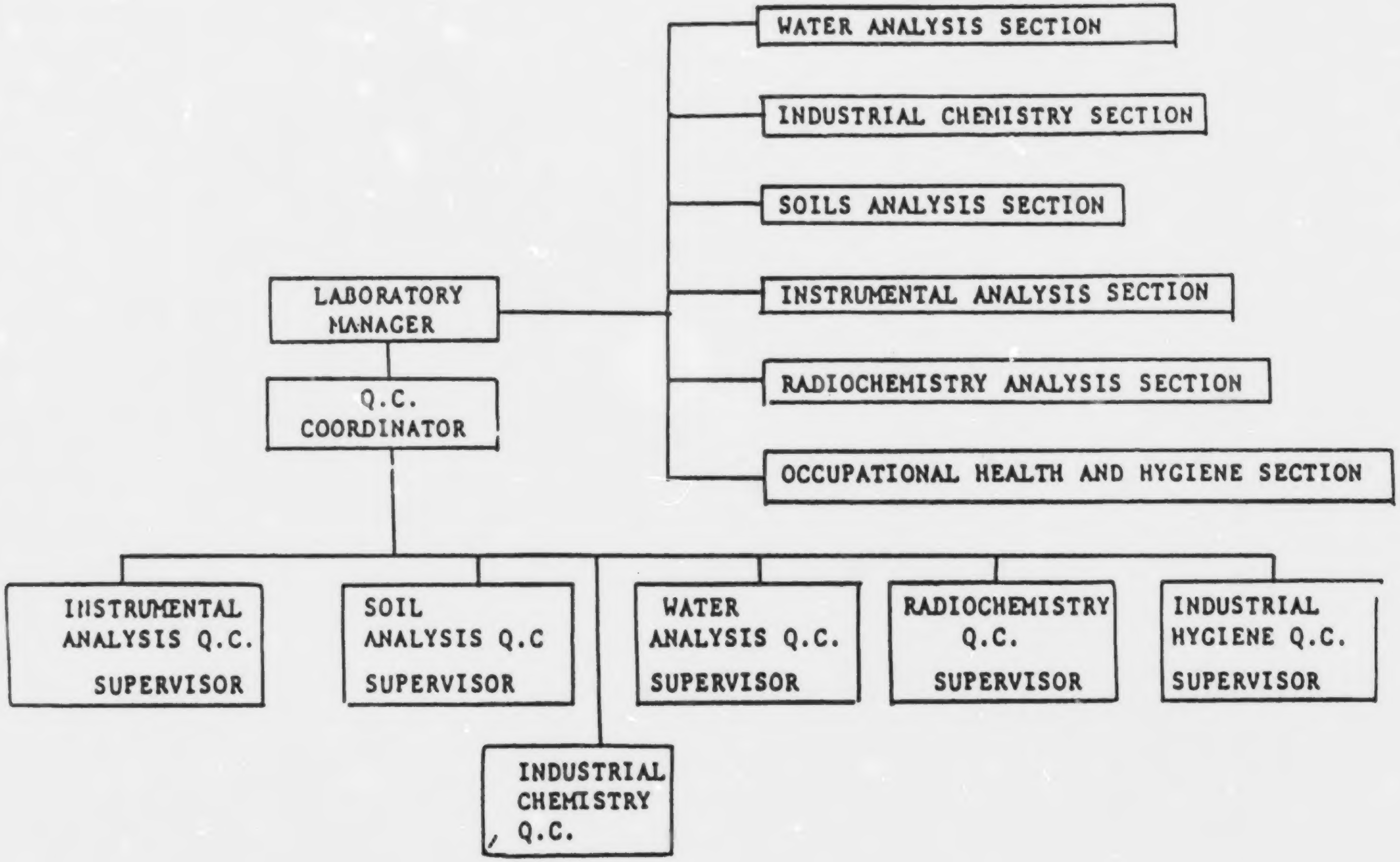
- Carry out monitoring, record keeping, statistical techniques and other functions required.

Quality Control Operating Principles

Record Keeping: Each sample is assigned a laboratory number and the analysis parameters requested are tabulated in a log book.

Reporting Practice: Each analysis report is prepared in triplicate. One copy is sent to the client and the other copies are filed in the specific project file. All raw data used to calculate each parameter are filed and stored in locations dedicated to that parameter and is retained for a period of two years. This practice allows re-checking of measurement data and calculation should it be necessary. Where possible, the estimated precisions of all data are included. Data obtained for standard reference materials and duplicates are also kept.

FIGURE 5.2 LABORATORY QUALITY CONTROL ORGANIZATION (MONENCO)


LABORATORY MANAGER
Q.C. COORDINATOR
WATER ANALYSIS SECTION
INDUSTRIAL CHEMISTRY SECTION
SOILS ANALYSIS SECTION
INSTRUMENTAL ANALYSIS SECTION
RADIOCHEMISTRY ANALYSIS SECTION
OCCUPATIONAL HEALTH AND HYGIENE SECTION
INSTRUMENTAL ANALYSIS Q.C. SUPERVISOR
SOIL ANALYSIS Q.C SUPERVISOR
INDUSTRIAL CHEMISTRY Q.C.
WATER ANALYSIS Q.C. SUPERVISOR
RADIOCHEMISTRY Q.C. SUPERVISOR
INDUSTRIAL HYGIENE Q.C. SUPERVISOR

Sample Storage: Samples are routinely stored for a minimum of 6 months. When space is available, each sample is retained in storage for a period of two years.

Instrument Calibration: Prior to the measurement of a parameter for a batch of samples the instrument and method is calibrated using appropriate dilutions of certified reference solutions or sources. The calibration procedure and measurement methodology is documented for reference purposes, in internal laboratory handbooks.

Calibration Interval: Each method and instrument was calibrated each time a batch of samples was analyzed and not less frequently than one per day. This interval is based on the degree of usage. All data and historical records pertaining to the calibration and maintenace of the instrumentation are retained for a period of 3 years.

Environmental Conditions: Laboratory conditions were controlled to the degree necessary to ensure required accuracy. The area was free of dust, vapours and vibration. Each instrument was not located close to equipment that produced vibration, chemical emissions or noise. The laboratory area was maintained at a temperature of 21-22°C. The analytical balances and electronic equipment for radiochemistry were located in an air conditioned environment with a filtered air supply.

Preventive Maintenance: The preventative maintenance program included cleaning, lubricating, adjusting and testing of all instruments and visual and electronic examination of the instrumentation on a regular basis. Its purpose is to increase measurement system reliability.

Use of Certified Reference Materials: Reference materials used in this project have been summarized above. In circumstances where reasonable agreement between the known and found composition of the CRM is not obtained, then all samples analyzed in that batch are reanalyzed. Agreement is obtained prior to reporting of data. In circumstances where CRM's were not available, 5% of each sample batch were reanalyzed and a sample that has been previously analyzed and reported was substituted for the CRM.

Interlaboratory Testing Programs: Monenco participated in:

1) Environment Canada, 2) Alberta Environment, 3) Saskatchewan Environment, 4) Western Enviro-Agricultural Laboratories Association, 5) U.S. EPA, and 6) CANMET programs.

5.3.3 Results of QA Program

A comparison of the measured values of reference solutions to certified values are given in Table 5.6 for analysis of porewater and surface water samples by Monenco for the year 1985.

TABLE 5.6(a) RESULTS OF MONENCO QA/QC PROGRAM (1985) FOR REFERENCE AND CONTROL SAMPLES

Radionuclide	Reference Solution	Activity[1] (Bq/mL)	Result[2] (Bq/mL)
Ra-226	RAY.44[3]	0.99	0.97 to 1.02
Th-228	RLZ.44[3]	1.49	1.40 to 1.55
Po-210	RBZ.44[3]	3.52	3.40 to 3.60
Ra-228	$Th(NO_3)_4 \cdot 4H_2O$	4.08	3.75 to 4.25
Pb-210	RBZ.44[3]	3.52	3.30 to 3.70

[1] Sources prepared from 1 mL of these solutions are used daily to calibrate instrument.

[2] These reference solutions are routinely used as control samples. One control for up to ten samples for Ra-226, Th isotopes and Po-210 determinations. Two controls for Ra-228 and Pb-210 determinations. Control samples vary between 0.5 mL to 10 mL of reference solutions. This column gives results obtained in our lab during 1985.

[3] All obtained from Amersham Corporation.

5.4 Chemex Laboratories (Chemex Labs Ltd.), Vancouver, B.C.

Chemex Laboratories was the prime laboratory for tailings, solids, porewater, high vol filters and vegetation tissues and a check laboratory for surface water.

5.4.1 Laboratory Methods of Analysis (Chemex)

Sample Preservation and Preparation

Liquid Samples: It was assumed that any water samples for dissolved radionuclides were field-filtered and preserved prior to shipment to the laboratory. Any water samples for total radionuclides were also assumed to be acidified in the field; they were subsequently digested in the laboratory using hot concentrated nitric and perchloric acids prior to analysis.

Solid Samples: Tailings solids and subtailings soils were dried at 50 Deg. C and ring ground to -200 mesh to ensure sample homogeneity.

The standard digestion procedure for all prepared solid samples was dissolution using a hot concentrated mixture of nitric, perchloric and hydrofluoric acids, followed by a pyrosulfate fusion of any undissolved residue, if necessary. Subsamples for radionuclide analysis exceed 0.5 gms in order to minimize uncertainty due to the counting statistics. Specific analytical procedures are outlined below.

Vegetation Samples: Vegetation subsamples of 5.0 gm were digested with a mixture of nitric, perchloric and hydrofluoric acids to give a completely clear digest with no undissolved residue. Detection limits for analysis are as follows: Ra-226: 0.002 Bq/g; Pb-210: 0.01 Bq/g; Total U: 0.01 ug/g; Th-230: 0.005 Bq/g, Th-232, Th-228: 0.001 Bq/g. These detection limits are for vegetation samples and are approximately ten times higher than for soils.

Beaver: A suitable aliquot of tissue was weighted, dried and digested with a mixture of nitrate, perchloric and hydrofluoric acid. Similar procedures to solids and vegetation were used for radionuclide analysis.

Specific Analytical Procedures

(a) Pb-210

A tracer solution of stable lead and bismuth was added prior to digestion. Bismuth was then solvent-extracted and its recovery determined by atomic absorption spectrophotometry. Bismuth was then precipitated as bismuth oxychloride and beta-counted to measure Bi-210, the first daughter of Pb-210 and assumed to be in equilibrium with Pb-210 by virture of its short half life. The detection limit for Pb-210 was 0.05 Bq. (CANMET, 1979).

(b) Po-210

An aliquot of the sample digest solution is reduced with ascorbic acid, heated to 90° C and polonium-210 is allowed to deposit spontaneously onto a silver disc. The disc is then alpha-counted to determine Po-210 activity. The absolute detection limit for Po-210 is 0.01 Bq. (CANMET, 1979).

(c) Ra-226

A tracer solution of Ba-133 was added prior to digestion. Radium was subsequently dissolved, separated, purified and co-precipitated with $BaSO_4$. The overall chemical yield was determined by gamma counting of Ba-133; Ra-226 was then determined by alpha spectroscopy. The detection limit for Ra-226 is 0.01 Bq. (CANMET, 1979).

(d) Ra-228

Radium-228 and other radium isotopes were separated by co-precipitation with lead sulphate, re-dissolved and purified by co-precipitation with barium sulphate. The barium (radium) sulphate was stored to allow the ingrowth of Ac-228, the first daughter of Ra-228 and known to grow into equilibrium with Ra-228 by virtue of its short halt life. Actinium-228 was then extracted from the precipitate, purified by solvent extraction and co-precipitated with lanthanum oxalate. The lanthanum (actinium) oxalate was then beta-counted to an absolute detection limit of 0.05 Bq. (CANMET, 1979).

(e) Thorium Isotopes

- Th-230

A tracer solution of Th-234 was added prior to digestion, as well as lanthanum chloride carrier and barium nitrate holdback carrier for radium. Thorium was co-precipitated with lanthanum hydroxide, purified and co-precipitated with lanthanum fluoride. The thorium precipitate was than beta-counted for Th-234 to measure the overall yield and then Th-230 is determined by alpha spectroscopy. The detection limit for Th-230 is 0.02 Bq. (CANMET, 1978).

- Th-232

Thorium-232 was determined by three different methods, alpha spectroscopy, gamma spectroscopy (neutron activation analysis) and colorimetry. The alpha spectroscopy procedure is as outlined for Th-230. The gamma spectroscopy procedure is conventional neutron activation analysis in which the gamma ray activity of the daughter product, Pa-233, is compared to the activity of standard reference materials. The determination of Th-232 by colorimetry as performed using arsenazo III following separation and purification of Th-232 by solvent extraction. (Talanta, 1961).

Porewater samples high in ferrous iron were treated by ion exchange techniques to remove iron and uranium in order to produce better quality alpha spectra. Sample aliquots were digested with aqua regia to oxidize iron to the ferric state. Sample residues were then dissolved in 9M hydrochloric acid and added to a column of anion exchange resin (chloride form). Iron and uranium, which form anionic chloro-complexes are strongly adsorbed whereas thorium, which does not form anionic chloro-complexes, passes through. Th-232 was determined by colorimetry routinely and samples with elevated activity were cross-checked by either gamma spectroscopy or alpha spectroscopy. (Palei, 1970).

o Th-228

Thorium-228 was determined by both alpha spectroscopy and gamma spectroscopy. The alpha spectroscopy procedure is as described above for Th-230. The gamma spectroscopy procedure involved the direct measurement of Th-228 by measurement of its gamma ray at 238 keV in comparison with standard reference materials.

(f) Total Uranium

Natural uranium was determined fluorimetrically as its fluoride complex following extraction into methyl isobutyl ketone from an acid-deficient aluminum nitrate solution. The detection limit for uranium was 0.1 ug. (ASTM, 1982, Vol. 31, Method D2907B).

Atmospheric Components - Special Procedures

Dustfall: The entire sample was evaporated to dryness and digested with hot nitric, perchloric and hydrofluoric acids to dissolve the radionuclides. A small fraction of the liquid sample was removed for fluorimetric uranium analysis; the remaining solution was halved, one half for Pb-210 determination and the other half for Ra-226 and Th isotope determinations by sequential radionuclide analysis. Detection limits are as outlined above under "Specific Analytical Procedures".

Hi-Vol Filters: Samples were collected on glass fibre filters and up to six filters were combined in a composite at the request of SENES Consultants Ltd. The filters wre dissolved in their entirety using a mixture of hot concentrated nitric, perchloric and hydrofluoric acids. A composite of blank filters was analyzed with each batch lot of ten samples to correct for any residual radionuclides in the filters. A small fraction of the clear digest solution was removed for fluorimetric uranium analysis; the remaining solution was halved, one half for Pb-210 determination and the other half for Ra-226 and Th isotope determinations by sequential radionuclide analysis. Aliquots of NBS - traceable standard radionuclide solutions were analyzed with each batch of ten samples. Typical analyses of these standard solutions are presented in Table 5.9, Part B.

5.4.2 Quality Assurance/Control Program (Chemex)

The Chemex quality assurance program consists of the analysis of primary and secondary reference materials, the replicate analysis of samples, frequent measurement cross-calibration, participation in interlaboratory control programs and the use of control charts for instrumental calibration. Laboratory technicians review data initially and perform check analyses if appropriate. Analytical data are then reviewed by the quality assurance coordinator before final certificates are generated.

Laboratory Quality Control Program

Reference Materials: Certified reference materials were routinely analyzed with each batch of twenty samples. Reference materials were analyzed wherever feasible, but in-house reference materials prepared internally, were also available for use in order not to deplete supplies of certified reference materials.

Certified reference materials were analyzed with each batch of tailings solids and vegetation samples. For the analysis of 14 tailings solids, reference materials included CANMET SRM's DH-la, DL-la and UTS-1. For the analysis of 21 vegetation samples, reference materials included CANMET SRM's CLV-1 and CLV-2. For the analysis of tailings porewaters, dustfill and hi-vol filters, aliquots of NBS-traceable standard radionuclide solutions were analyzed with each batch of 10 samples since there are no standard reference materials available for samples of these types. Results of the data for reference materials are indicated in Section 5.4.3 and Table 5.9.

Measurement Cross-Calibration: Many elements can be determined by several different techniques. This permits systematic cross-checking to ensure the validity of data. Table 5.7(a) lists the variety of techniques available for some of the more important elements required for this project. Results are presented in Section 5.4.3 and Table 5.9.

Routine Quality Control Procedures: Routine Quality Control procedures involve sample storage, analysis of blanks, use of carriers and radiotracers, instrument calibration, duplicate analysis, and data reporting.

TABLE 5.7(a) ANALYTICAL TECHNIQUES (CHEMEX LABS)

Element	Analytical Technique
Ra-226	Gross Alpha, Alpha Spectroscopy, Gamma Spectroscopy
Pb-210	Beta Counting, Gamma Spectroscopy
Th-232	Alpha Spectroscopy, NAA, Colorimetry, ICP (total Th).
U	NAA (delayed neutron counting), NAA (gamma spectroscopy), fluorimetry, volumetric
Th-228	Alpha Spectroscopy, Gamma Spectroscopy

Key:
NAA = Neutron Activation Analysis
AAS = Atomic Absorption Spectroscopy
ICP = Inductively Coupled Plasma Emission Spectroscopy

TABLE 5.7(b) ESTIMATES OF PRECISION (95% Confidence Interval)

Element	Solutions (%)	Solids (%)
Uranium-238	10	5
Thorium-232, -228	15	5
Thorium-230	20	15
Radium-226, -228	15	10
Lead-210	15	15
Polonium-210	15	15

(i) Sample Storage: Porewater samples were filtered and preserved in the field. In the laboratory, the samples were stored at 4°C. Bottles were opened as infrequently as possible to minimize the oxidation of the high concentrations of ferrous iron. Multiple withdrawals of sample aliquots were made whenever bottles were opened.

(ii) Analysis of Blanks: Reagent blanks, procedural blanks and filter blanks were analyzed with each batch of samples and corrections made if appropriate.

(iii) Carriers and Radiotracers: The use of carriers and radiotracers were used to determine overall chemical yields for procedures including Ra-226, Pb-210 and Th isotopes.

(iv) Instrument Calibration: Control charts are maintained to monitor the alpha and beta backgrounds of counting equipment and also to monitor the efficiencies of standard alpha (Am-241) and beta (Cs-137) sources. The alpha spectroscopy system has been calibrated using NBS-traceable alpha sources including Gd-148, Am-241, Ra-226, Rn-222, Po-218 and Po-214 which cover an energy range of 3.18 to 7.69 MeV.

(v) Duplicate Analyses: Duplicate analyses were performed for each batch of samples provided that the availability of sample material permitted. Dustfall and hi-vol filters were not analyzed in this way because of the small sample weights available. Table 5.9 presents typical data obtained by the duplicate analyses of several batches of porewaters.

(vi) Data Reporting: All data entering the Chemex Labs database were verified by double data entry. The data were initially entered by one data entry operator and then independently confirmed by a second data entry operator. If the two sets of data did not match exactly, any entry discrepancies were immediately listed by the computer and corrected.

Accuracy and Precision

For the radionuclides analyzed as part of this project, the accuracy of the analyses may be assessed by an examination of the data presented for reference materials in Table 5.9(a). The precision of the data is estimated to be within the confidence intervals given in Table 5.7(b). These "confidence limit" estimates are based upon the participation by Chemex in various interlaboratory audits as well as on the reproducibility of replicate analysis.

TABLE 5.8: CHEMEX PARTICIPATION IN CCRMP

CCRMP Reference Material	Major Elements Certified
UTS-1, UTS-2, UTS-3, UTS-4	U, Th-230, Pb-210, Po-210
DL-1a, DH-1a, BL-4a, BL-5	Pb-210, Ra-226
BL-5	U
DL-1a	U, Th
DH-1a	U, Th
CLV-1, CLV-2	Pb-210, Po-210, Ra-226, Th-230, U
RGU-1	U
RL-1	U
Fish Meal, Fish Bone	U, Pb-210, Po-210, Ra-226, Th-230

Interlaboratory Audits

Chemex participates in numerous interlaboratory testing programs sponsored by government agencies. For radionuclide analysis, the most useful exchange program is the Canadian Certified Reference Materials Project (CCRMP) sponsored by CANMET. The participation by Chemex for uranium/ores and tailings and the various radionuclides is summarized in Table 5.8. In the certification of the uranium tailings standards UTS-1, UTS-2, UTS-3 and UTS-4 (for Th-230, Th-232, Pb-210, and Po-210), Chemex points out the following: of the major commercial analytical firms, only Chemex had no radionuclide values rejected as outliers during the detailed statistical analysis that followed the Round Robin study of these uranium tailings standards. These confidence limit estimates are based upon the participation of four uranium ores which were certified by Chemex Labs for Pb-210 activity by two different analytical techniques, radiochemical beta counting and instrumental gamma spectroscopy.

5.4.3 Results of Quality Assurance Program (Chemex).

Results of the Quality Assurance Program are given in Table 5.9 under the following headings:

5.9(a)	Analytical Data for Reference Material
5.9(b)	Measurement Cross Calibration Data
5.9(c)	Internal Replicate Analysis (Duplication) Data

Reference Materials

A comparison of measured concentrations in reference materials with the certified value is given in Table 5.9(a). Tailings solids results are given in Part 4. Results for tailings porewater and Hi-Vol filters are given in Part B. Vegetation sample results are given in Part C. The values found are generally within 1-2%.

Measurement Cross-Calibration

Table 5.9b presents analytical data for a number of different elements analyzed in tailings solids and porewaters at various stages of this project as part of the measurement cross-calibration program.

Duplicate Analysis

Duplicate analysis is the splitting of a sample by the laboratory and the analytical measurement of each subsample. The results of duplicate analysis is given in Table 5.9c.

Table 5.9 ANALYTICAL DATA FOR REFERENCE MATERIALS (CHEMEX)

A. Tailings Solids

The following references materials were analyzed with the fourteen tailings solids:

Reference Material	Isotope	Found	Certified
DL-1a	U	115 ppm	116 ± 3 ppm
UTS-1	Th-230	3.58, 3.56 Bq/g	3.6 ± 0.6 Bq/g
DH-1a	Pb-210	30.3 Bq/g	30.75 ± 0.92 Bq/g
DH-1a	Ra-226	31.0, 30.8 Bq/g	31.5 ± 1.1 Bq/g

B. Tailings Porewaters, Hi-Vols and Dustfall Samples

Aliquots of NBS-traceable standard radionuclide solutions were analyzed with each batch of ten samples. Radionuclides analyzed in this fashion included Ra-226, Pb-210, Th-230, Th-228 and Th-232. Typical results are presented below:

Porewaters: Chemex No. A8513090

Isotope	Bq Added	Bq Found
Th-230	0.62	0.61
Th-232	0.41	0.37
Th-228	0.41	0.37

Hi-Vol Filters: Chemex No. A8515564 and A8512569

Isotope	Bq Added	Bq Found
Th-230	0.059	0.054
Th-232	0.040	0.042
Th-228	0.040	0.039
Ra-226	0.49	0.50
Pb-210	0.34	0.35

C. Vegetation Samples

The reference materials CLV-1 and CLV-2 were analyzed together with the single batch of 21 vegetation samples:

Reference Material	Isotope	Found	Certified
CLV-1	Th-230	0.30 Bq/g	0.31 ± 0.04 Bq/g
CLV-1	Ra-226	0.69 Bq/g	0.70 ± 0.03 Bq/g
CLV-2	Pb-210	0.064 Bq/g	0.070 ± 0.006 Bq/g

Table 5.9 RESULTS OF MEASUREMENT CROSS CALIBRATION (CHEMEX)

A. Tailings Solids: Chemex No. A8511618

Parameter: Pb-210 (Bq/gm)

Sample	Gamma Spectroscopy	Beta Counting
SO-02 A6/PS	2.7	3.0
SO-04 B2/SS	8.9	8.7
SO-04 B3/SS	9.3	9.4
SO-05 A1/PS #2	8.2	7.9
SO-05 G1/PS	13.5	12.7
SO-05 G5/PS	0.6	0.6

Parameter: U (ppm)

Sample	Neutron Activation (Delayed Neutron Counting)	Fluorimetry
SO-01 A7/PS	44.7	42
SO-02 A3/PS	48.6	44
SO-02 D1/SS	10.3	7.6
SO-02 D2/SS	34.5	30
SO-05 G1/PS	79.1	76
SO-05 G5/PS	10.2	8.8

Parameter: Th-228 (Bq/gm)

Sample	Alpha Spectroscopy	Gamma Spectroscopy
SO-01 A7/PS	0.24	0.20
SO-02 A3/PS	0.20	0.22
SO-02 A6/PS	0.27	0.20
SO-02 D2/SS	0.30	0.27
SO-04 B2/SS	0.95	0.86
SO-04 B3/SS	1.09	0.96
SO-05 G3/PS	1.18	1.24
SO-05 G5/PS	0.08	0.08

B. Tailings Porewaters: Chemex No. A8513090

Parameter: Th-232 (Bq/L)

Sample	Colorimetry	Gamma Spectroscopy
GW-01/E	5.2	5.9
GW-02/V	40.9	38.5
GW-02/VI	45.2	41.0
GW-02/VII	33.1	28.9

Table 5.9 RESULTS OF MEASUREMENT CROSS CALIBRATION (CHEMEX)

Parameter: Ra-226 (Bq/L)

Sample	Alpha Spectroscopy	Gross Alpha Counting
GW-02/IV	18.1, 19.3	18.7
GW-04/E	3.49	3.27
GW-04/F	3.06	2.99
GW-05/D	4.27	4.49
GW-05/K	3.39	3.31

C. **Tailings Porewaters: Chemex No. A8515615**

Parameter: Th-232 (Bq/L)

Sample	Colorimetry	Gamma Spec.	Alpha Spec.
GW-01/F	0.86	-	0.96
GW-02/V	-	35.8	37.8
FQ-01/VII	-	19.4	18.9

Parameter: Ra-226 (Bq/L)

Sample	Alpha Spectroscopy	Gross Alpha Counting
GW-03/B	3.56	3.66
GW-03/D	4.14	4.58

Table 5.9 DUPLICATE ANALYSES (CHEMEX)

A. Chemex No. A8513090

Sample No.	U (ppm) Analysis #1	Analysis #2	Reported
GW-02/C	2,800	2,800	2,800
GW-04/C	435	465	450
GW-04/E	195	205	200

Sample No.	Th-230 (Bq/L) Analysis #1	Analysis #2	Reported
GW-02/V	321	339	330
GW-02/VI	475	485	480

B. Chemex No. A8515615

Sample No.	U (ppm) Analysis #1	Analysis #2	Reported
GW-02/III	2,850	2,950	2,900
GW-02/C	26,500	26,000	26,500

Sample No.	Th-230 (Bq/L) Analysis #1	Analysis #2	Reported
GW-02/III	7.4	7.4	7.4
GW-02/V	335	365	350
GW-02/VII	173	179	176

5.5 Saskatchewan Research Council

The Saskatchewan Research Council (SRC), Saskatoon, Saskatchewan, was a check laboratory on Surface Water Samples.

5.5.1 Sample Preservation and Preparation

It was assumed by SRC that the following sample handling and preservation procedures were used by Field Personnel.

Radionuclides

Water: For each radionuclide determination, one litre of sample was preserved with 10 mL conc. HNO_3. If it was necessary to distinguish between dissolved and suspended species, an additional one litre was filtered with a 3 micron filter and then acidified to 1% HNO_3.

Trace Metals:

Samples were preserved with 1% HNO_3.

Laboratory Sample Handling Procedures (SRC)

Preparation of Water Samples: Samples were stored in plastic containers. All water samples were analyzed as quickly as possible after receipt to minimize changes in chemical composition. If evaporative concentration of water samples were required for trace metal determinations, extreme precautions were taken to prevent contamination or losses during this process.

5.5.2 Laboratory Methods of Analysis (SRC)

Summary of Analytical Methods for Radionuclides

All radiochemical samples were analyzed according to the procedures outlined in the "Analytical Methods Manual for the National Uranium Tailings Program" by Dean and Chiu (1984) or a variation thereof. Variations are documented below.

Lead-210

The procedure used for the determination of lead-210 is detailed in CANMET Report 78-22 (p. 20) and was developed in the SRC Analytical Laboratory. The detection limit was 0.5 pCi (0.02 Bq). The precision was ±5% (1 sigma) for levels above 10 pCi (0.4 Bq).

Radium-226

Radium-226 was determined according to the gross alpha counting procedure in CANMET Report 78-22. Alpha spectroscopy was performed on representative samples to confirm the absence of Ra-223 and Ra-224 interferences. The detection limit for this procedure was 0.1 pCi (0.004 Bq). The precision at the 10 pCi (0.4 B1) level was approximately ±5% (1 sigma).

Thorium-230

The radiochemical procedure used for Th-230 is identical to that in the NUTP Analytical Procedures Manual (Dean and Chiu, 1984). After isolation, Th-230 was co-precipitated with $Ce(OH)_3$, filtered onto a fine pore-size membrane filter and measured by alpha spectroscopy. The detection limit was approximately 0.2 pCi (0.01 Bq). The precision at the 10 pCi (0.4 Bq) level was approximately ±7% (1 sigma).

Uranium

Uranium was determined by delayed neutron counting if the level is above 0.1 ug/g or 0.1 ug/mL. The precision of this method is ±2% (1 sigma) or levels above 10 ppm. Samples containing less than 0.1 ug/mL were analyzed by the conventional UV excited fluorescence method (Centanni et al, 1956). With a preconcentration of liquids this method can detect down to 0.5 ug/L. The precision was approximately ±8% (1 sigma) for levels above 20 ug/L.

Summary of Analytical Methods for Trace Metals

Trace metals were routinely determined by plasma emission spectrometry except for As and Se which were determined by atomic absorption spectrometry. Using a 5-fold preconcentration all metals could be detected below the 10 ug/L range and many at the 1 ug/L level. In the sub-ppm range both techniques had a relative standard deviation of approximately ±5% (1 sigma).

5.5.3 Quality Assurance/Control Program (SRC)

The SRC QA/QC program consists of use of reference samples and replicates, participation in interlaboratory comparison programs, sample logging procedures and recommendations for sample handling.

Quality Assurance - Replication and Use of Standards

Blind duplicates, spiked samples and blanks were routinely processed. These internal quality control checks constitute approximately 10% of the analytical workload. All radiochemical procedures were calibrated and checked with NBS traceable standards (some directly from NBS and others from Amersham).

There are no Q.C. checks for the radium-228 measurements other than the series of standards (aged thorium nitrate and Alfa thorium oxide, 30 years old) which were run with each group of samples. Normally, four standards and one blank were analyzed with each set. Over the years, these standards and some spiked samples have given an overall analytical precision of ±7% (1 sigma). In addition, SRC has always been within the control limits for the USEPA interlab Ra-226, 228 program for the last 6-7 years.

Standard reference materials include the following: CANMET Uranium Ore Reference Standards BL-1, BL-2, BL-3, BL-4, BL-4a, BL-5, DH-1, DH-la, DL-1, DL-1a, CUP-1. CANMET Uranium Tailings Ref. Mat. UTS-1, UTS-2, UTS-3, UTS-4, UTS-5. CANMET Radiochemical Vegetation Ref. Mat. CLV-1, CLV-2. Amersham aged Thorium nitrate, ALFA thorium oxide, radium-226 solution RAY.44, barium-133 solution BDZ-72; lead-210 (polonium-210) solution RBZ.44; alpha ref. source AMR.33. National Bureau of Standards - radium-226 solution 4953-C. ICN CHemical and Isotope Division - reference beta source 77116. Spex Industries - certified solutions for all elements analyzed by atomic absorption or plasma-emission analysis. NBS standard reference materials - orchard leave, spinach, river sediments.

Quality Assurance - Interlaboratory Comparison Programs

The interlaboratory comparison programs in which SRC participated include:

> US EPA, Radiation Protection Bureau, Health and Welfare Canada, Ottawa; Air Pollution Technology Center, Environment Canada, Ottawa; Environment Canada; the Water Pollution Control Branch, Saskatchewan Environment, Regina; and CCRMP. The interlaboratory programs of significance to this project are:

- o the CANMET Certified Reference Materials Program for the determination of Ra-226, Pb-210, Th-230, Po-210 and Ra-228 in ores and uranium tailings (CANMET Reports 83-9E, 83-112(TR), 78-22 and recent unpublished studies).
- o USEPA -radium-226 and radium-228 in water
  - gross alpha and beta in water
  - uranium in water
  - iodine-131
  - gamma nuclides in water
  - gross alpha-gross beta, cesium-137 and strontium-90 on air filters
- o Health and Welfare Canada, Radiation Protection Service
  - uranium in urine
- o Environment Canada, Trace Metals in Water
  - in cooperation with Sask Environment

Quality Assurance - Laboratory QC Program

The laboratory Q.C. program is directed by the laboratory head and performed by the section supervisors (Lloyd MacDonald in radiochemistry, and Dr. Wo Yuen in general chemical analysis). All results are reviewed between the laboratory head and the section supervisors. Problems are analyzed and corrected on a daily basis.

Sample Identification and Recording Procedures: Upon receipt, samples were logged into the computer and given a group number. Then each sample was given a lab number and worksheets were printed out with proper analysis required. Samples were stored in a cool sample room until the analyst signed them out on the computer which records initials and date started. After removal from the cooler to begin analysis they are kept at room temperature until disposed of. Upon completion of analysis, samples were stored for 30 working days before discarding unless otherwise notified. SRC does not have sufficient cooler space to store all the current samples which are normally retained for six weeks.

Data Handling: All interlaboratory results and internal laboratory Q.C. results are stored in files and are not entered into the main computer data base because of problems that would occur with billing. These files contain all historical Q.C. data. When a client request Q.C. data, SRC must manually prepare a summary.

Instrument Calibration: All instruments are calibrated with each set of samples by analyzing a set of standards and blanks. Any change in the calibration curve results in readjustment of the instrument before analysis is continued. The low level radiation counters are checked against a calibrated source at the beginning of each week, or any time a change in counting efficiency is observed (i.e., when running standards).

Environmental Guidelines: The laboratory has a heating-air conditioning system which maintains room temperature at 24±1°C. SRC has experienced failure of the system on only two occasions in the past five years.

5.5.4 Results of Laboratory QA/QC program

The laboratory was requested to provide values of replicates and the measured values of reference standards. SRC was able to provide information on the known value of a reference standard and the measured value. These data are provided in Table 5.10 for the Gunnar field study. (The first number in each set of parenthesis is the known value of the analyzed standard. The second number is the result obtained). All results are pCi with the exception of Uranium which is ug/L for water and ug/g for solids.

TABLE 5.10: REFERENCE STANDARD VALUES AND MEASURED VALUES BY SRC

The first number in each set of parenthesis is the known value of the analyzed standard. The second number is the result obtained. All results are pCi, with the exception of uranium which is ug/L for water and ug/g for solids.

Gr. 84-1801 Jan.3/85 Rec'd Dec.13/84
Lab#12259-12265 Water

Pb210	(4.49, 4.7)
Po210	(4.49, 4.71)
Ra226	(120.4, 120.2);(12.04, 12.36)
Ra228	---
Th230	(50, 49.4)
U	(150, 152);(30, 32);(2000, 1900);(5000, 5200)

Gr. 85-438 Apr.2/85 Rec'd Mar.25/85
Lab#2705-2710 Water

Pb210	(44.9, 42.9)
Po210	(44.9, 44.2)
Ra226	(6.02, 5.9);(120.4, 117)
U	(30, 34);(2000, 2100)

Gr. 85-1345 Aug.19/85 Rec'd Aug.7/85
Lab#10661-10665 Water

Ra226	(12.04, 12.2)
Pb210	(4.49, 4.6)
Th228	---
Th230	(50, 47.6)
Th232	---
U	(200, 191)

Gr. 85-1373 Aug.28/85 Rec'd Aug.12/85
Lab#10743-10747 Water

Pb210	(44.9, 42.1)
Ra226	(60.2, 61)
Ra228	---
Th230	(50, 52.1)
U	(150, 154);(1000, 950)

5.6 University of Waterloo Microbiological Laboratories

Bacterial analyses were conducted at the University of Waterloo under the direction of Dr. C. Mayfield. The methods used by this laboratory are described below. There were no duplicate analyses by a second laboratory in this case.

(i) Aerobic Plate Count

Samples were diluted in sterile 0.85% saline and decimal serial dilution prepared. Aliquots of 0.1 mL were transferred to the surface of soil extract agar plates (1 kg of soil autoclaved in 1 L of 100 mL standard soil extract medium added to 900 mL distilled water plus yeast extract (0.5 g), ferric phosphate (0.01 g), glucose (2.5 g) and agar (15 g). The plates were incubated at 25°C for 7 to 14 days and the colonies counted.

(ii) Anaerobic Deep Tube Count

Sterile test tubes were filled with Reinforced Clostridial Medium (Difco) and made anaerobic by evacuation and refilling with nitrogen gas. The tubes were steamed before use to melt the agar and maintained at 45°C to keep the agar molten.

Samples were collected anaerobically under a stream of nitrogen gas and transferred to a flask containing anaerobic diluent (Baar's medium). Dilutions were made in the diluent and quantities transferred to the deep agar tubes. After incubation at 25°C for 14 days, the colonies within the deep agar tubes were counted and expressed as "numbers of anaerobic bacteria per gram".

(iii) Sulphate Reducing Bacteria Count

Samples were taken in the same way as for anaerobic deep tube counts. Samples were diluted in Baar's medium and incubated in deep thin tubes with Baar's medium solidified with agar (Pankhurst, 1971). The tubes were incubated for 30 days at 25°C and the number of black colonies (sulphate-reducing bacterial colonies) were counted. The MPN method was used to estimate the number of sulphate-reducing bacteria in the original sample based on the dilution series and the presence or absence of black colonies in the tubes.

(iv) Most Probable Number (MPN) Sulphur-Oxidizers Estimate

Sulphur-oxidizing media was prepared as 0.1 g elemental sulphur per 10 mL medium in individual test tubes (Tuttle et al, 1968). The modified nine K medium was made up as follows (Silverman and Lundgren, 1959).

	per litre
K_2HPO_4	0.5 g
$Ca(NO_3)_2 * 4H_2O$	0.01 g
$(NH_4)_2 SO_4$	3.0 g
KCl	0.1 g
$MgSO_4 * 7H_2O$	0.5 g
Distilled H_2O	100 mL

The pH of the nine K medium was adjusted to 3.0 with sterile H_2SO_4. Each test tube was given 10 mL of nine K medium and sterilized in flowing steam for one hour on three successive days.

Procedure

The aerobic sample-taking and dilution procedure is identical to that outlined under the aerobic plate count method. The dilutions were selected so that the series of tubes yielded all positives at the lower dilution and all negatives at the higher dilution. After the dilutions were made, using a 1 mL pipetman, 1 mL of the appropriate dilution was aseptically pipetted into each of three test tubes containing sulphur-oxidizers media. Five dilution series consisting of three tubes each were inoculated.

When setting up the sulphur-oxidizing MPN, both positive and negative controls were used so that comparisons to these controls can be made during the evaluation of the MPN tubes. For the positive control, 1 mL of a pure culture of Thiobacillus thiooxidans was added to each of four test tubes containing sulphur-oxidizing media. The negative control consisted of four test tubes of sterile sulphur-oxidizing media.

All tubes were incubated at 25°C for three weeks (Harrison, 1978; Tuttle et al, 1968). After incubation, the tubes were observed and compared against the positive and negative controls. The elemental sulphur of the positive control dropped to the bottom of the tube with growth, as compared with the sterile control, where it floated on top of the media. This was one indication of growth, but a pH indicator dye was also used to observe a pH change in the medium during growth. Two drops of a 1% solution of basic fuchsin was then added to each tube. The controls were used as examples of positive and negative colours. The negative tubes gave a cherry red colour, and the positive tubes gave a purple colour (basic fuchsin is purple at pH 1.2 to 1.5 and red at 1.5 to 3.0).

The most probable number (MPN) method was used to estimate the number of viable sulphur-oxidizing bacteria present in the sample. To obtain the MPN, the number of positive tubes from each of three selected dilutions was determined and compared to an MPN table (FDA, 1977).

(v) Most Probable Number (MPN) Iron Oxidizers Estimate

The following nine K media were made up in two solutions (Silverman and Lundgren, 1959; Butler, 1985).

Solution #1

	per litre
K_2HPO_4	0.5 g
$Ca(NO_3)_2 * 4H_2O$	0.1 g
$(NH_4)_2 SO_4$	3.0 g
KCl	0.1 g
$MgSO_4 * 7H_2O$	0.5 g
Distilled H_2O	800 mL

The pH of this solution was adjusted to 3.0 with sterile sulphuric acid and placed in an Agarmatic automatic sterilizer and dispenser to be sterilized.

Solution #2

$FeSO_4 * 7H_2O$	44.0 g
Distilled H_2O	200 mL

The pH of the second solution was adjusted to 3.0 with sterile sulphuric acid and filter sterilized (0.45 micron filter).

When the Agarmatic (Solution #1) was tempered (55°C), Solution #2 was added aseptically through the injection port using a sterile 50 mL syringe. The mixture was dispensed at approximately 10 mL per test tube.

Procedure

The aerobic sample-taking and dilution procedure is identical to that outlined under the aerobic plate count method. The dilutions were selected so that a series of tubes yielded all positives at the lower dilution and all negatives at the higher dilution. After the dilutions were made, 1 mL of the appropriate dilution was aseptically pipetted into each of three test tubes containing iron oxidizing media. Five dilutions series, consisting of three tubes each, were inoculated.

The iron oxidizing media will gradually chemically oxidize over time so both positive and negative controls make evaluation of the tubes much easier. For the positive control, 1 mL of a pure culture of Thiobacillus ferroxidans was added to each of four test tubes containing iron oxidizing media.

All tubes were incubated at 25°C for three weeks (Harrison, 1978; Tuttle et al, 1968).

After incubation, the tubes were observed and compared against the positive and negative controls. The positive controls had flakes of heavy dark red-brown precipitate near the top on the sides of the test tube. The negative control tubes and those tubes in which growth did not occur had a light yellow-brown precipitate due to autooxidation.

The most probable number (MPN) method was used to estimate the number of viable sulphur oxidizing bacteria present in the sample. To obtain the MPN, the number of positive tubes was determined from each of three selected dilutions and reference made to an MPN table.

5.7 X-Ray Laboratories Limited, Don Mills, Ontario

5.7.1 Laboratory Methods of Analysis and Detection Limits

The laboratory method of analysis and detection limits are shown in Table 5.11.

Table 5.11 RARE EARTHS: METHODS OF ANALYSIS AND DETECTION LIMITS

Symbol	Element	Method*	Detection Limit (ppm)
Y	Yttrium	DCP	1.000
La	Lanthanium	NA	0.100
Ce	Cerium	NA	1.000
Pr	Praseodynmium	DCP	2.000
Nd	Neodymium	NA	3.000
Sm	Samarium	NA	0.010
Eu	Europium	NA	0.050
Gd	Gadolinium	DCP	2.000
Tb	Terbium	NA	0.100
Ho	Holmium	DCP	2.000
Er	Erbium	DCP	0.500
Tm	Thulium	DCP	0.500
Yb	Ytterbium	NA	0.050
Lu	Lutetium	NA	0.010

* DCP - Direct Current Plasma (DCP) Analyser

NA - Neutron Activation

5.8 Further Analyses of QA/QC Program

As indicated at the beginning of the appendix, **quality assurance** involves a total program for assuring the reliability of monitoring data. Quality control is the routine application of procedures for controlling the measurement process. For this study, quality assurance has involved several aspects including:

- correct sampling and field preservation techniques,
- analysis of sequential field samples,
- submission of duplicate samples submitted "blind" to the same laboratory,
- submission of duplicate samples to two different laboratories (the primary laboratory and a check laboratory),
- selection of reputable laboratories with a proven track record of analysis whose rate structure was economical,
- laboratory QA/QC procedures,
- checks on the analytical results such as:
  - cation-anion balance,
  - correlations between radionuclides and elemental analysis (e.g., total Th to Th-232; Pb210-stable Pb),
  - consistency of data with each other and expected geochemical behaviour.

As a result of the program, several discrepancies were obvious early. Others became apparent later in the program. These discrepancies resulted mainly from the interlaboratory audit (analysis of duplicate samples by two different programs). This led to submission of samples with known composition to the laboratories for analysis. The composition was essentially a calcium-iron-sulphate matrix containing Ra-226 and Th-230. A more detailed description of this program is given below (Section 5.6.2).

In this section, a qualitative picture of the quality assurance results are given and then the results of the QA audit with known samples are given.

5.8.1 Qualitative Description of QA/QC Results

The focus of the analytical effort was the tailings porewater. This particular component was chosen to receive a major portion of the quality control and quality assurance effort because of a series of factors including: (1) accessibility of the sample locations on a year round basis so that one particular location could be repeatedly sampled over the duration of the program, (2) the tailings porewater contains the highest mobile inventory of both radionuclides and trace elements and is the most important component (in conjunction with the solids) for assessing long-term environmental significance, and (3) the tailings porewater contains relatively high levels of substances such as calcium, sulphate and iron which are known to interfere with analyses of certain elements and cause sample changes in the field, and thus should result in the highest levels of sampling and analytical variability.

The tailings porewater was sampled on every field trip to establish the temporal variability of parameters in a relatively stable area. This would allow the opportunity to calculate an overall variance for this type of data. Unfortunately, due to two field surveys, there are insufficient data to assess temporal variance. Rather, reference should be made to other tailings areas (e.g., Nordic with a more sustained data base). Samples were also collected from the same hole sequentially during the same sampling program in order to determine the range of variability associated with sequential sampling from the same location and at the same time.

For tailings porewater, surface water, atmospheric solids, tailings solids, and vegetation components, other measurements of quality assurance occurred. Samples were collected, mixed, and then split between laboratories to determine the range of interlaboratory variability or accuracy. Samples were collected and split so that blind replicates could be submitted to the same laboratory based upon separate batches in order to ascertain the degree of laboratory precision. Lastly, the laboratories replicated samples themselves in order to determine the degree of precision for various analyses as part of their own internal quality control program.

These data are presented on the data tables in the various technical appendices. The reader should interpret these as the use of the data dictates. These quality control analyses including all of the above categories amounted to about 10 - 20 percent of the total analyses undertaken. In addition to these quality control cross checks, the data were also scrutinized to determine its reasonableness. For analysis of aqueous samples, which involved major cations and anions, a calculation of an electroneutrality balance was made. In cases where the data was unacceptable, a check was requested. The corrected data are presented on the data sheets included in the appendices to this report. In some cases, repeat analyses and calculation checks still resulted in an unsatisfactory balance. The cause of the imbalance remains unsolved. This, however, applies to only a small percentage of the samples.

In some instances, discrepancies in data reported for blind replicates between laboratories were traced to inconsistencies in reporting format, and were corrected. In other cases, principally in the trace element analyses, certain pieces of data appear to be outliers. Values like these are left in the data set because they are the 'best' data available but it is recommended that these outliers be accounted for, if the data are to be used for modelling or other quantitative purposes.

In other instances, such as for stable lead, there is a consistent difference in the data between the check laboratory test and the main laboratory. These data are internally consistent as the blind replicates and internal quality control and assurance data shows, and are presented in the data table as reported after query by the project team. As the discrepancies for a couple of trace elements could not be resolved during the course of the program, a set of certified standards blended into a tailings porewater matrix were sent to each of the laboratories for analyses. These data are discussed below and should be used when interpreting the main body of data.

In general, for the types of analyses carried out in this study, given the types of matrices necessary to analyze in, the uncertainty associated with the major anions and cations is in the order of 30 percent at levels up into the parts per million or low parts per thousand levels. At the low parts per billion range the uncertainty is much larger being generally in the order of 2 to 5 times. The radionuclide analyses generally showed what would be considered to be relatively moderate levels in porewater for uranium mine tailings. The overall uncertainty associated with the analyses is judged to be about 100 percent at or near the 1 Bq/L level, although the precision within a given laboratory on a split sample or blind replicate was better than this. At lower levels, nearing the detection limits for the radionuclide concerned, the overall accuracy was less.

The data necessary for a statistical evaluation of the accuracy and precision are available in the appendix documents, but no statistical analyses have been carried out under the terms of reference of this study. Any statistical analysis of the data set should be carefully planned in order to derive the type of data necessary for future use of this information. In the above section, an outline of all the analytical and quality control procedures followed by the various laboratories participating in the study along with the routine detection limits that the laboratories claim to be achievable in clear solutions are given. These detection limits are not necessarily valid for the matrix of the runoff waters analyzed in this project. The results from the next section should be used to critique the effect of the matrix.

5.8.2 Analysis of Interlaboratory Comparison

Additional quality assurance analyses of the data have been made by calculating anion-cation balances and plotting various related parameters. These analyses are summarized in Tables 5.12 - 5.14 and Figures 5.3 to 5.14.

Cation-anion balances are presented in Table 5.12 for tailings porewater samples and in Table 5.13 for surface water samples. Not all ions are included in the balance, rather the major ions which make a reasonable contribution to the balance are included in the calculation. The cation portion of the balance is calculated using measured concentrations of aluminum, calcium, copper, iron (II), iron (III; = iron total minus iron II), potassium, magnesium, manganese, sodium, nickel, strontium, thorium, zinc, and hydrogen ion (pH). The anion portion of the balance is defined using sulphate concentrations.

The major problem in making the calculation is the assignment of the proper charge to iron (III) and to aluminum. Hydrolysis reactions alter the effective charge from a value of three. Problems can also result for the calculation of sulphate if the pH is below 2.0 because of the formation of HSO_4^-. Because the pH is generally above 2 and below 4 for most samples, the calculations are made assuming that iron and aluminum are not hydrolyzed and that sulphate is present as SO_4^{2-}.

An acceptance criteria also needs to be established. This is left for the reader to do. However, a few points are made. If anion and cation analysis is made on the same sample bottle, a reasonable cation-anion balance might be ± 3-5%. Because these analyses of Tables 5.12 and 5.13 were made on different sample bottles (Fe^{2+} measured in the field; cations upon a nitric-acid-preserved bottle; anions upon an unpreserved

Fig. 5.3 Plot of Electrical Conductivity Versus Acidity for Tailings Porewater

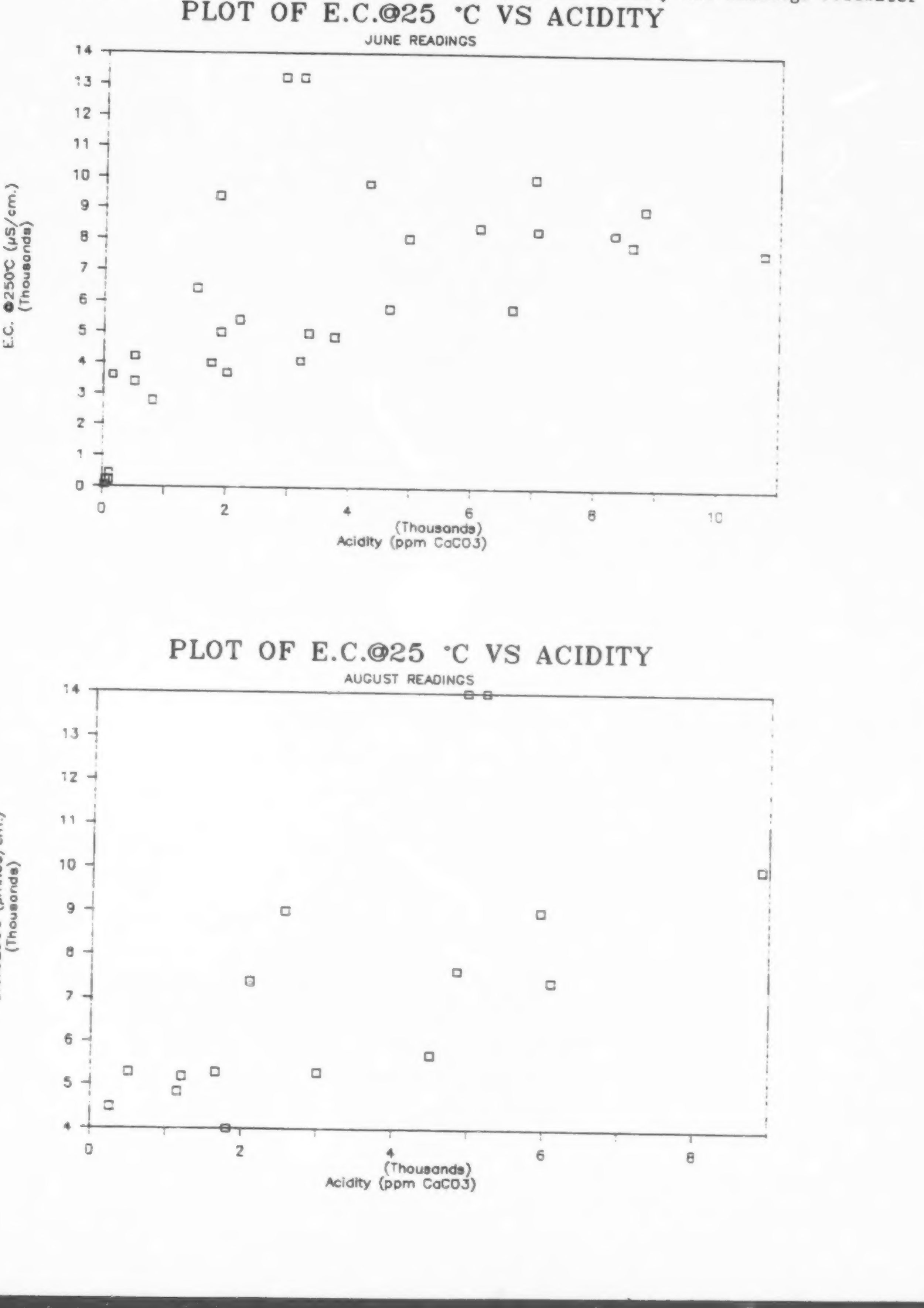
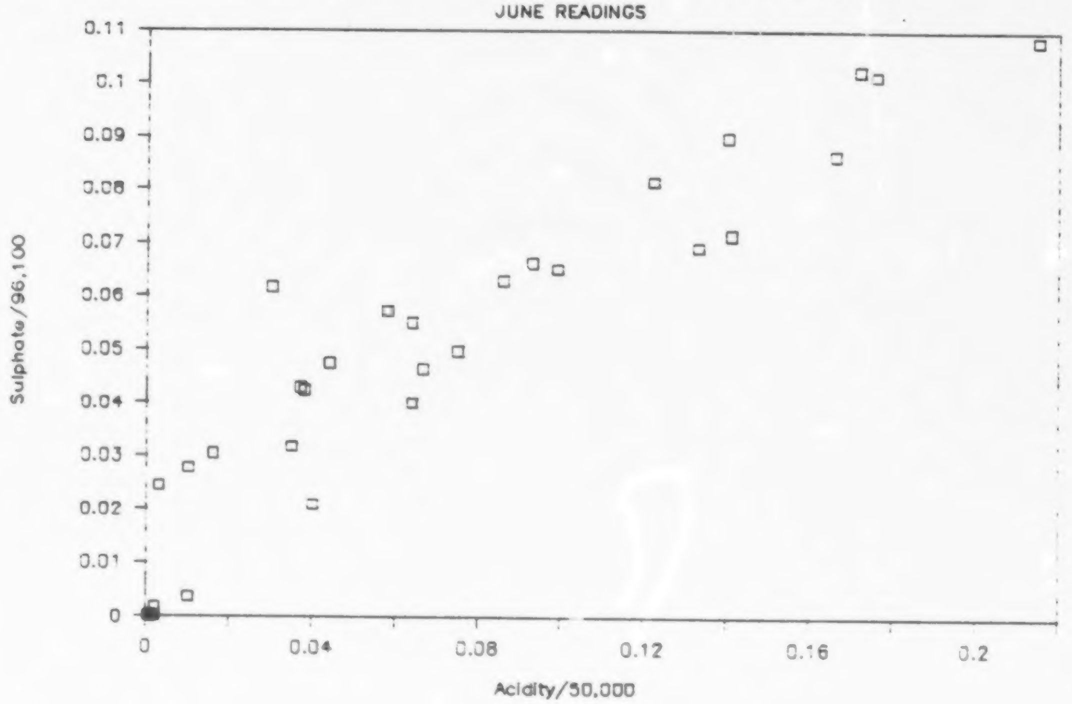


Fig. 5.4 Plot of Sulphate Versus Acidity for Tailings Porewater

PLOT OF SULPHATE VS. ACIDITY



PLOT OF SULPHATE VS ACIDITY

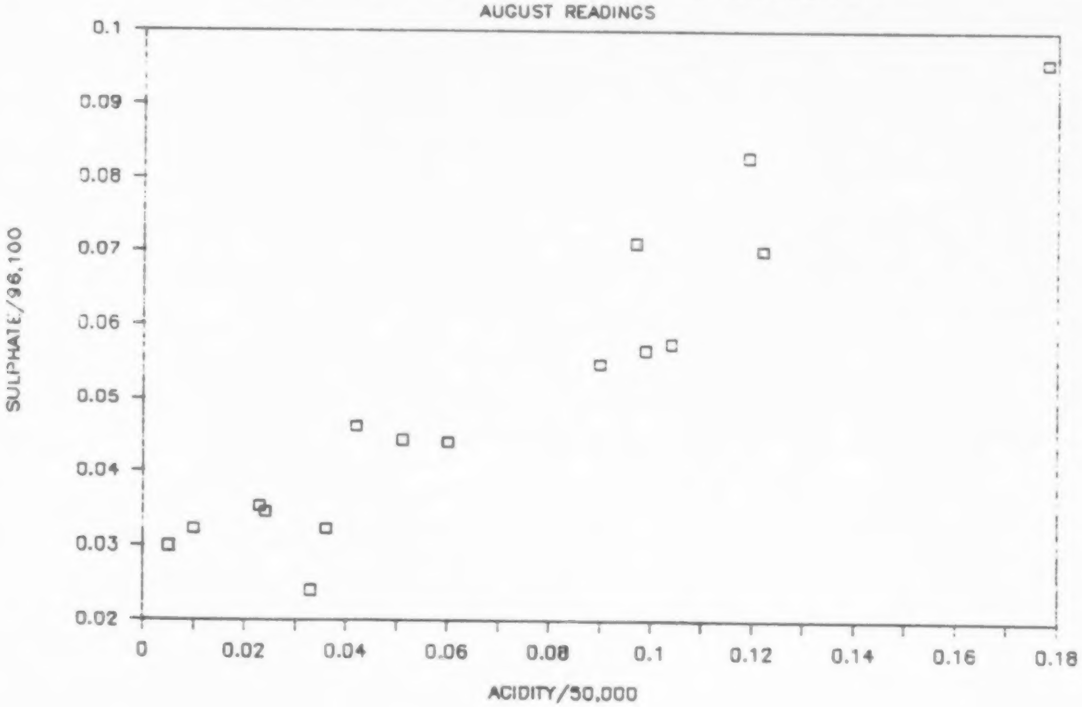
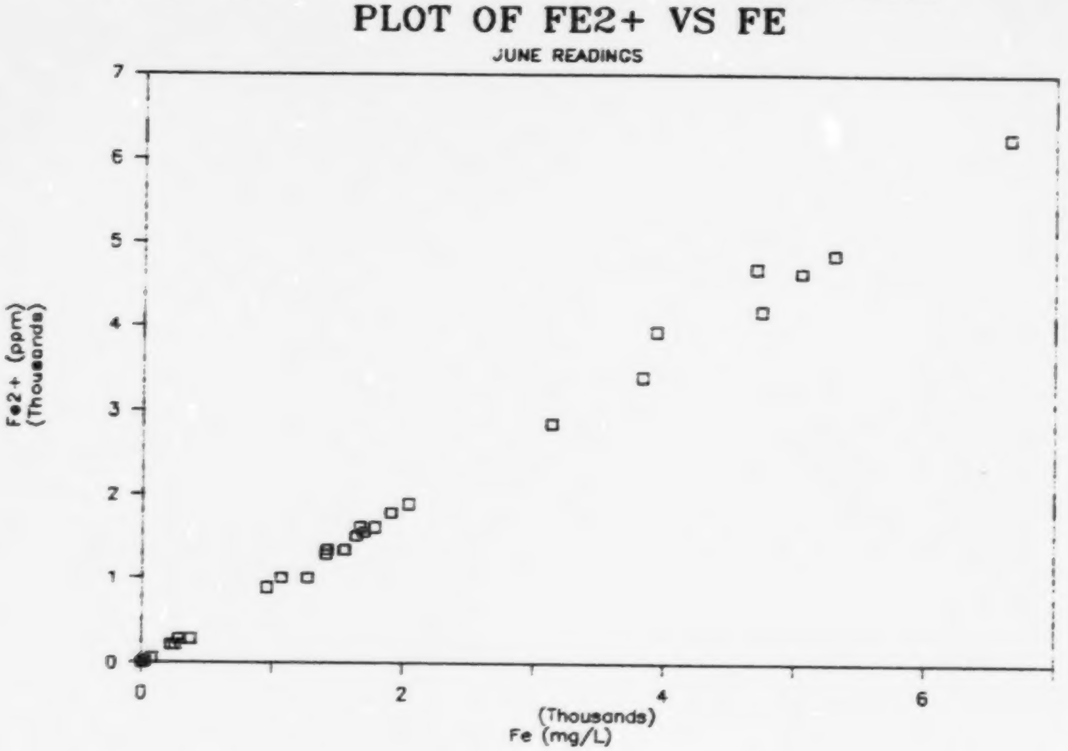


Fig. 5.5 Plot of Fe^{2+} Versus Acidity for Tailings Porewater



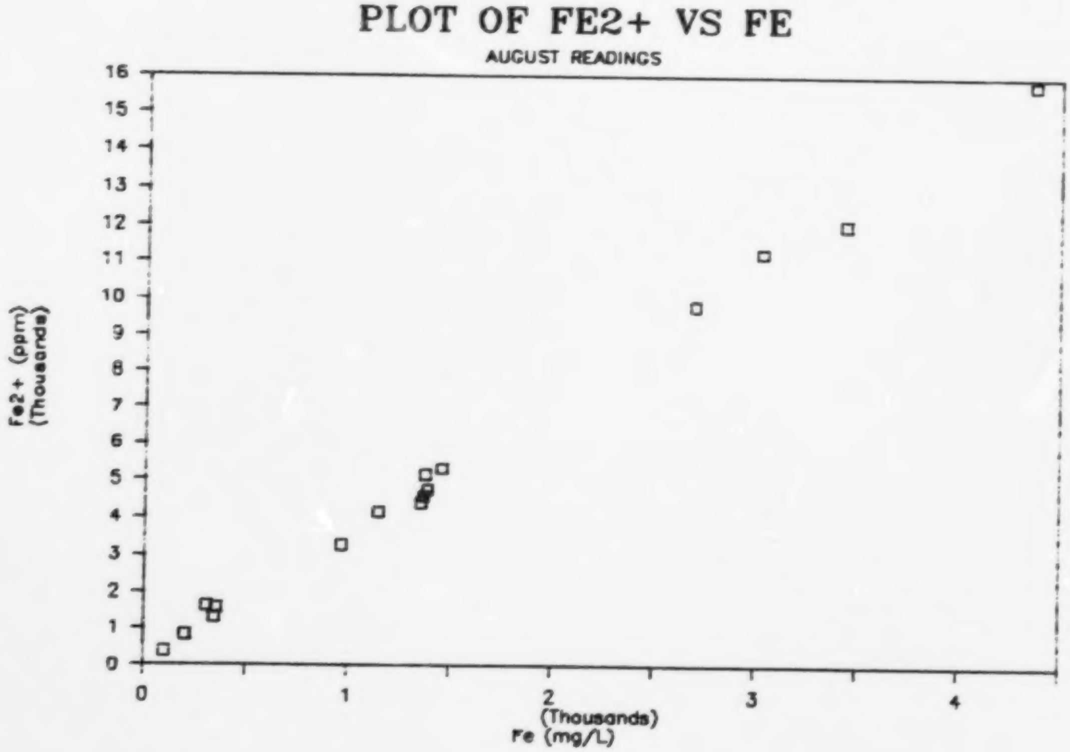


Fig. 5.6 Plot of Calculated Acidity (Y) Versus Measured Acidity (X) for Tailings Porewater

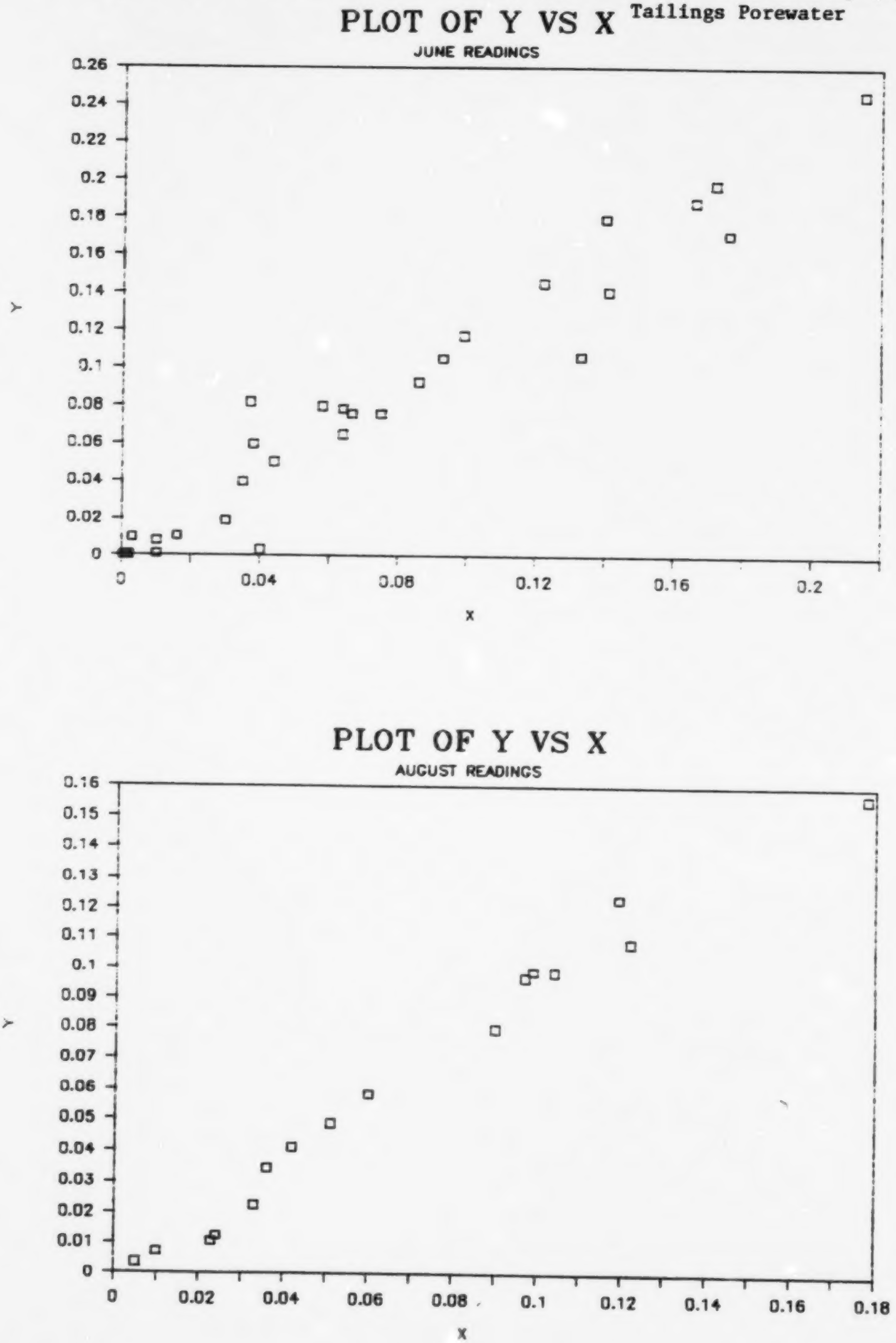


Fig. 5.7a Plot of Duplicate vs Value Above For Tailings Porewater - AL

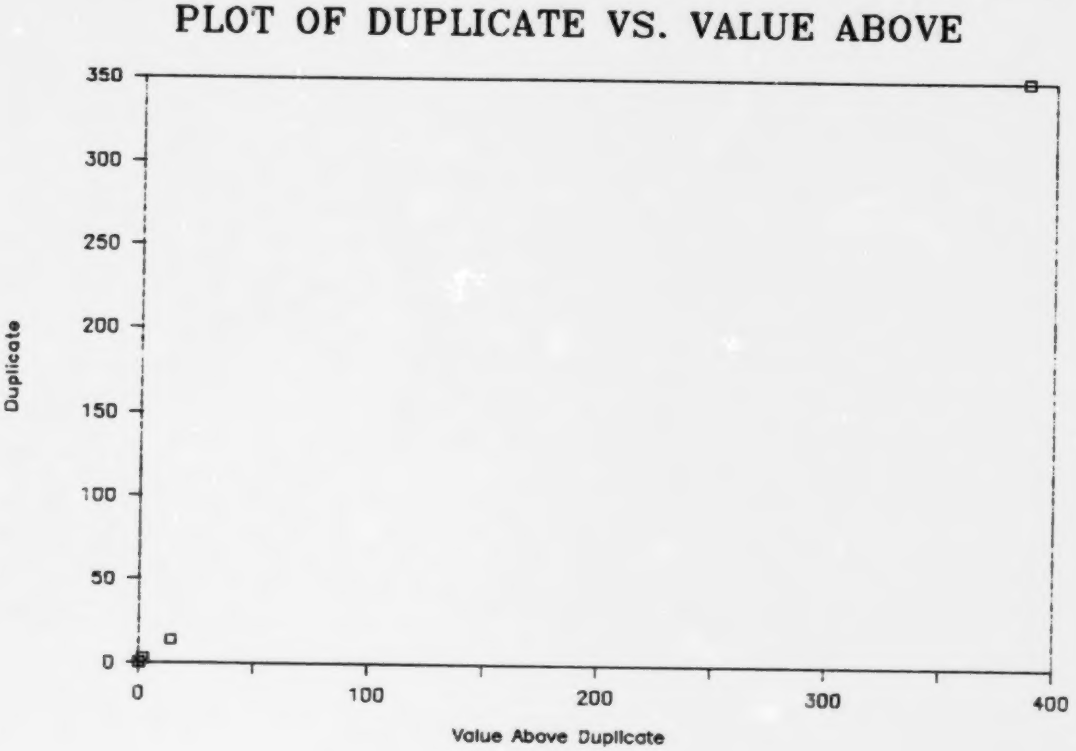


Fig. 5.7b Plot of Duplicate vs Value Above for Tailings Porewater - CA

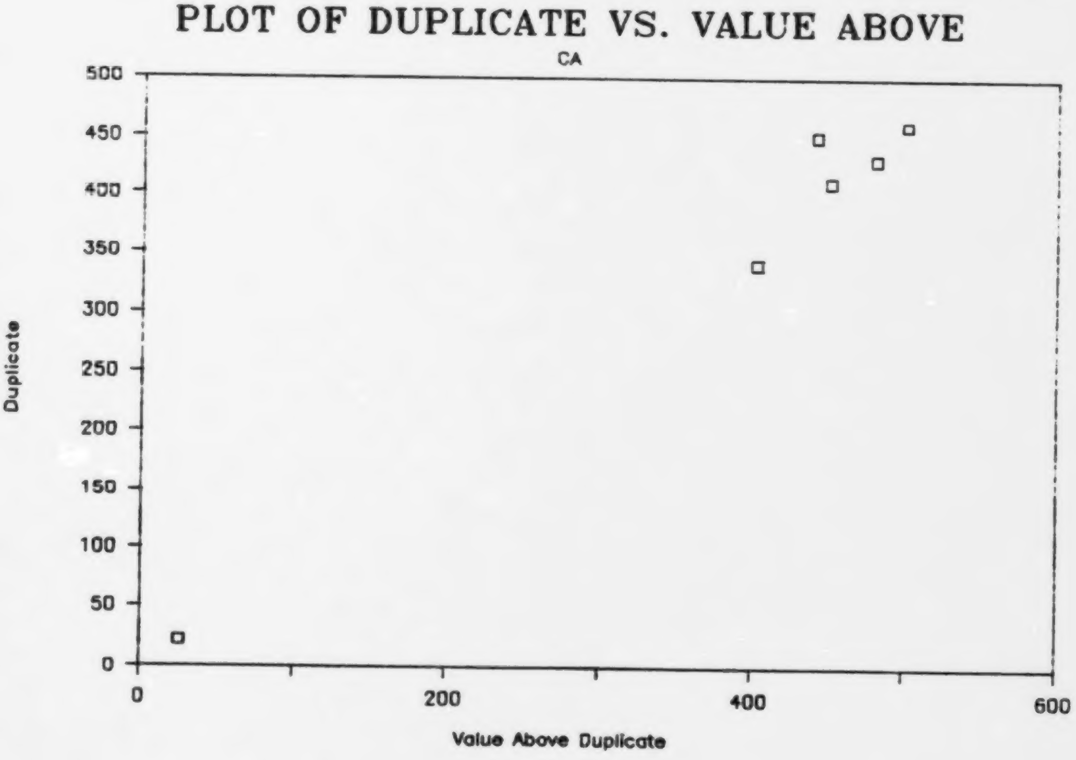


Fig. 5.7c Plot of Duplicate vs Value Above for Tailings Porewater - CR

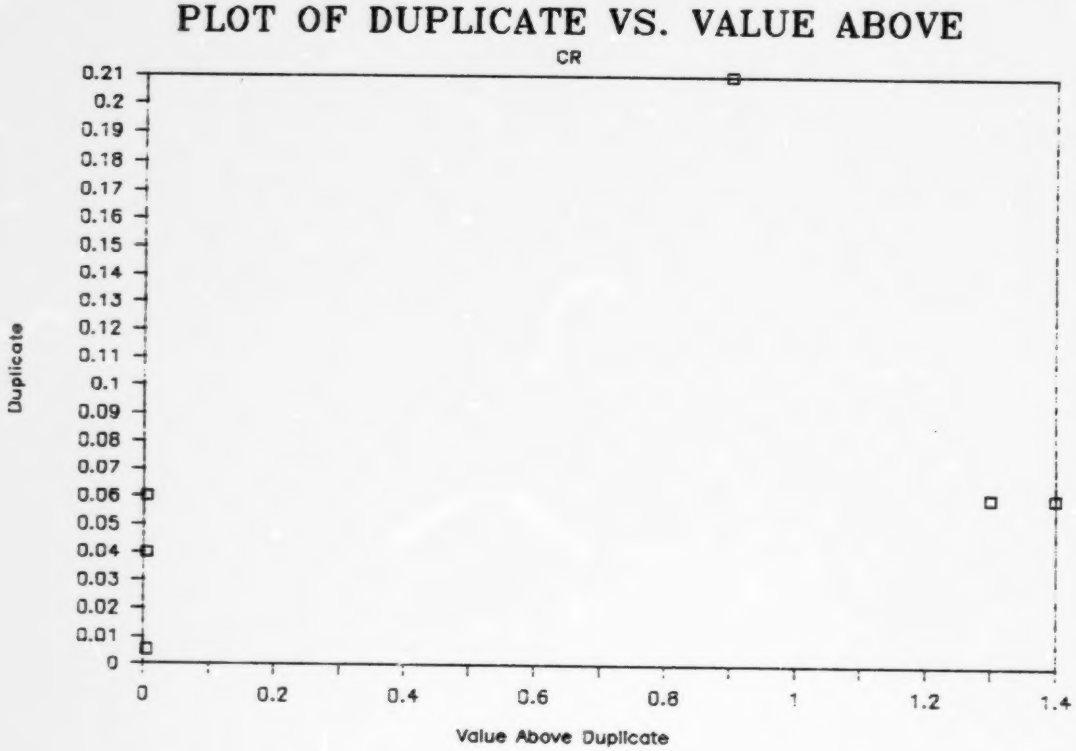


Fig. 5.7d Plot of Duplicate vs Value Above for Tailings Porewater - FE

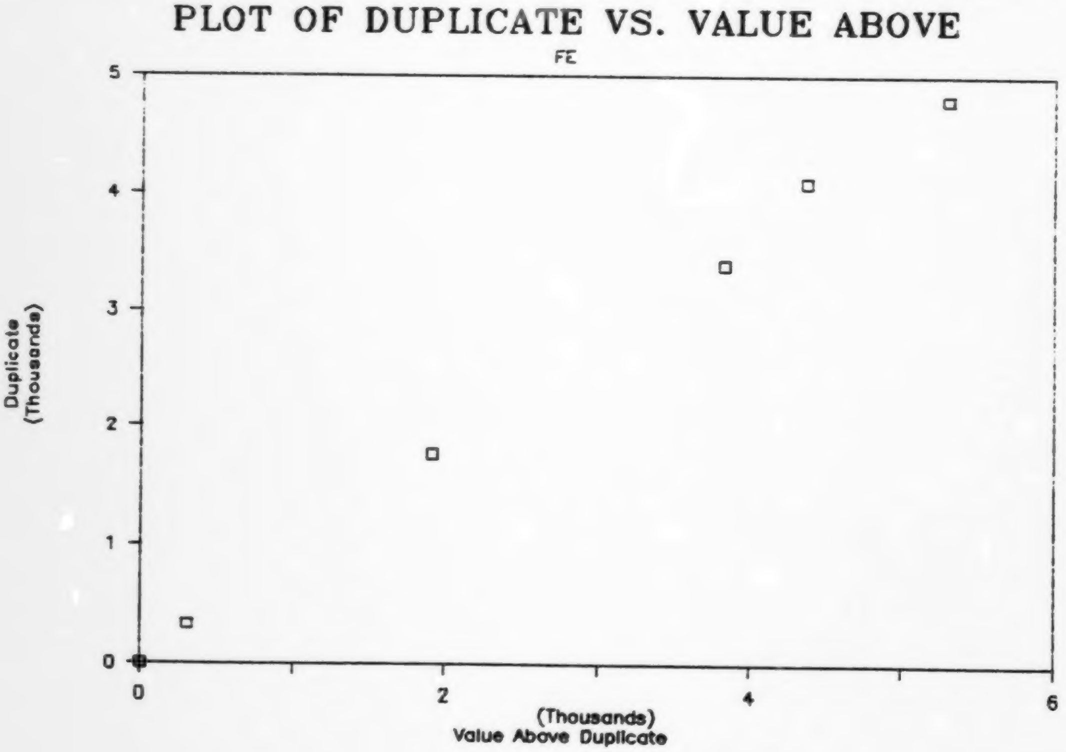


Fig. 5.7e Plot of Duplicate vs Value Above for Tailings Porewater - K

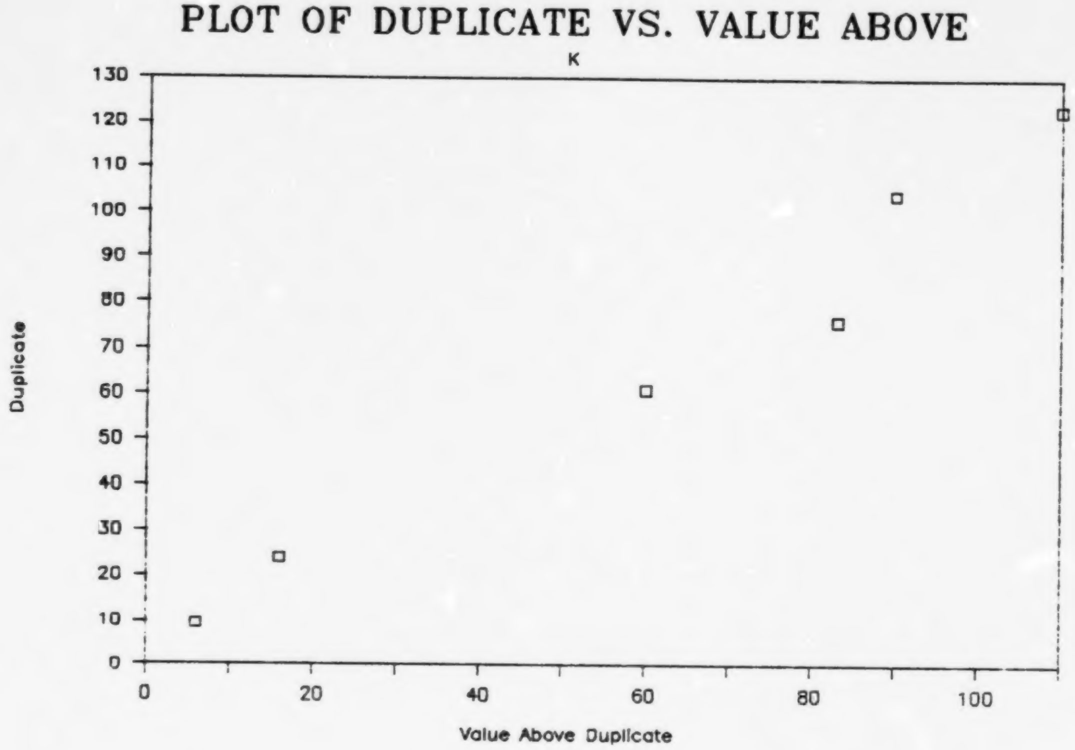


Fig. 5.7f Plot of Duplicate vs Value Above for Tailings Porewater - MG

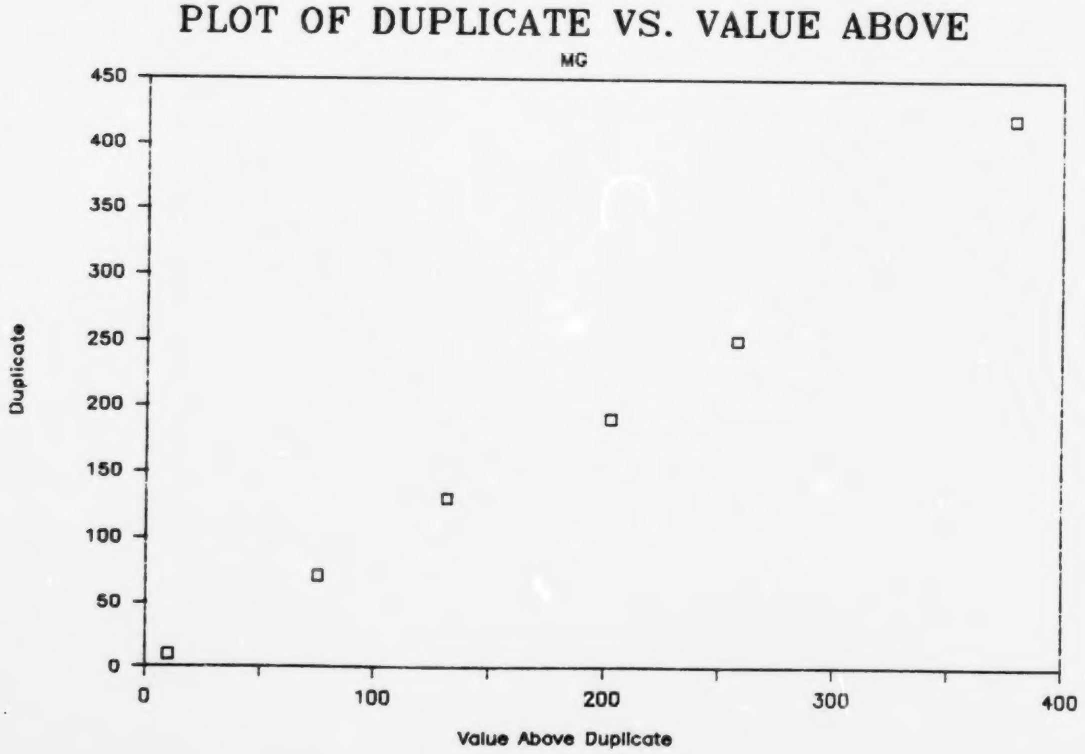


Fig. 5.7g Plot of Duplicate vs Value Above for Tailings Porewater - MN

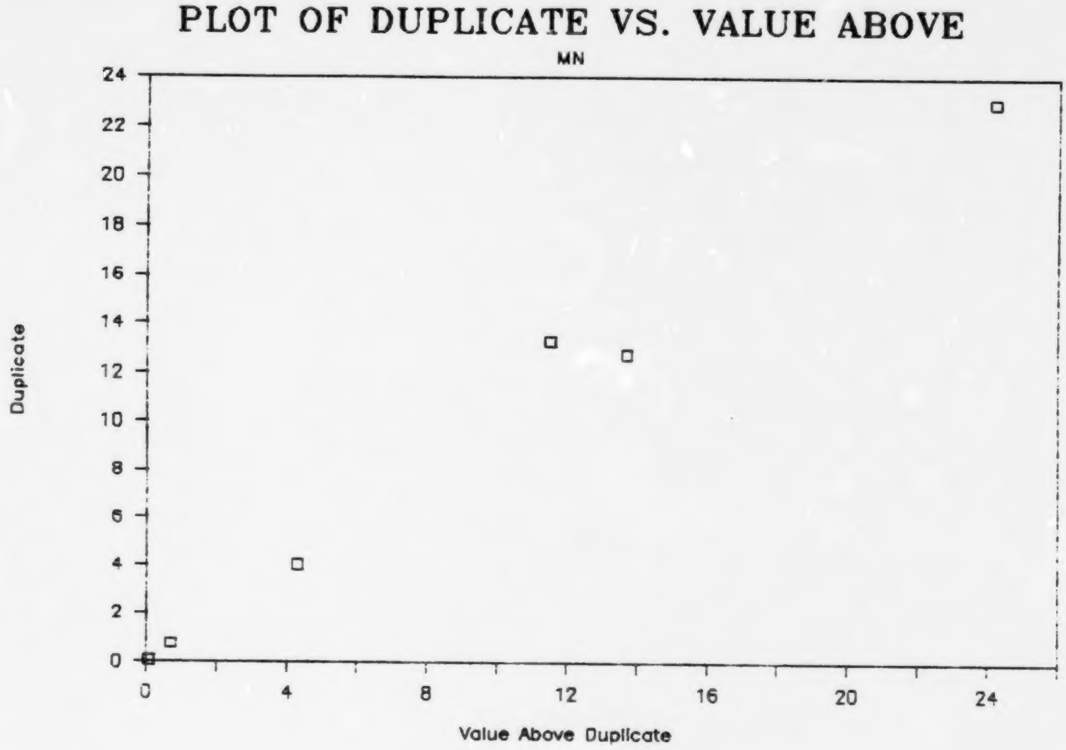


Fig. 5.7h Plot of Duplicate vs Value Above for Tailings Porewater - NA

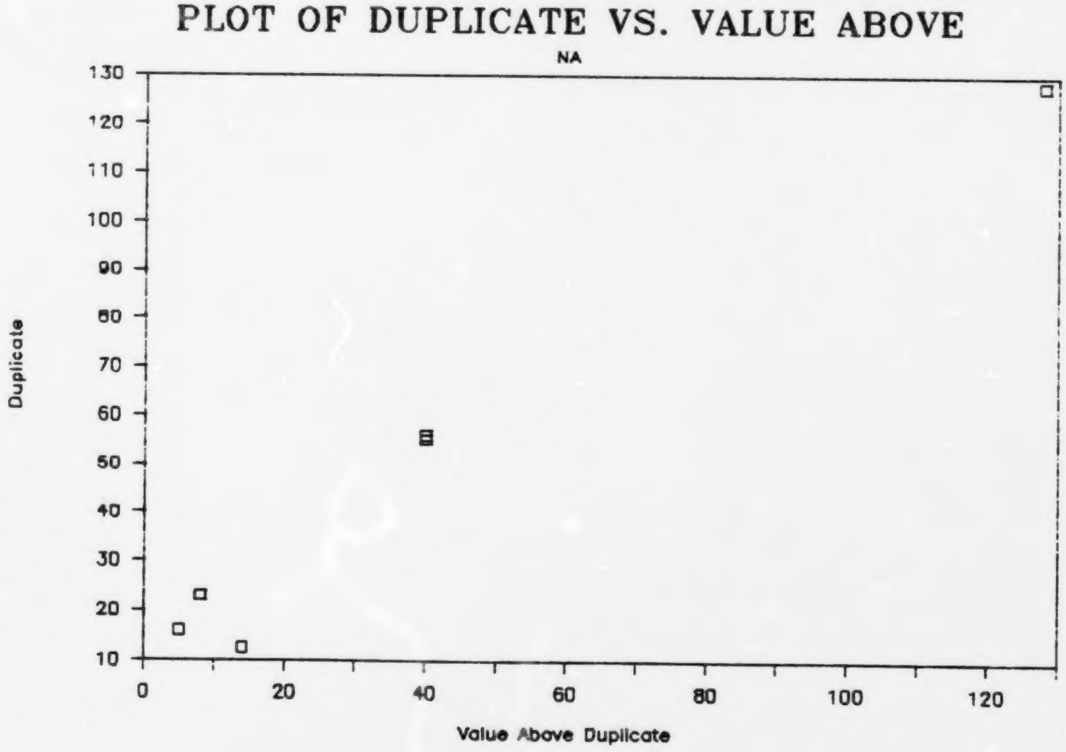


Fig. 5.7i Plot of Duplicate vs Value Above for Tailings Porewater - NI

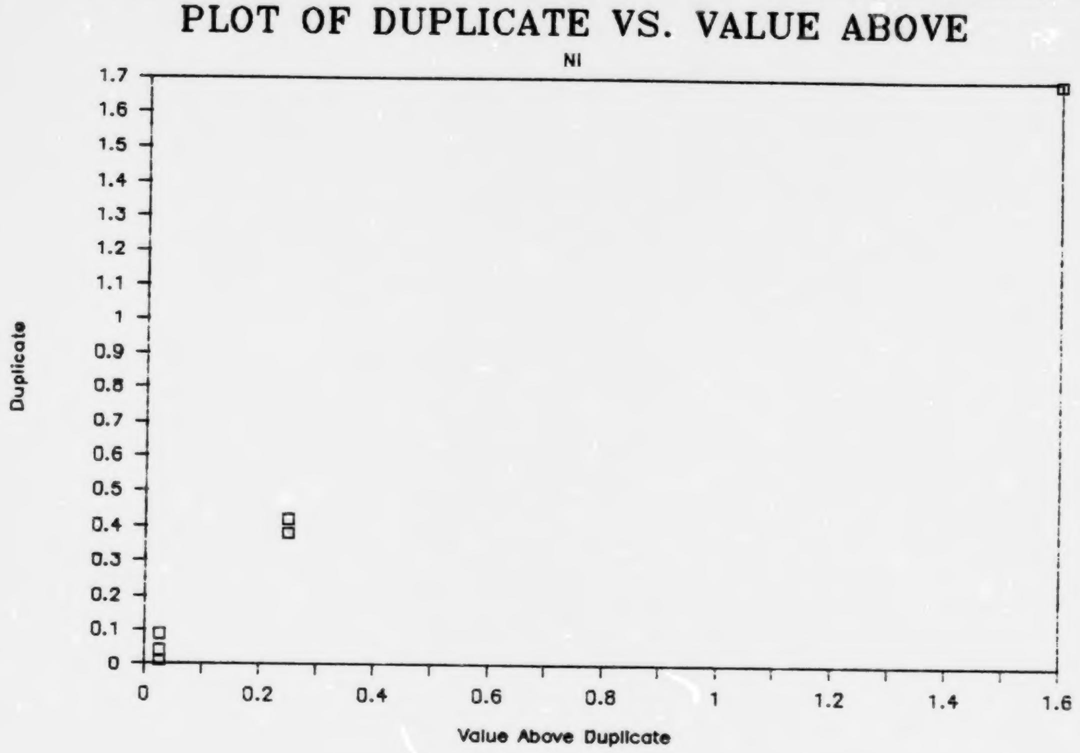


Fig. 5.7j Plot of Duplicate vs Value Above for Tailings Porewater - PB

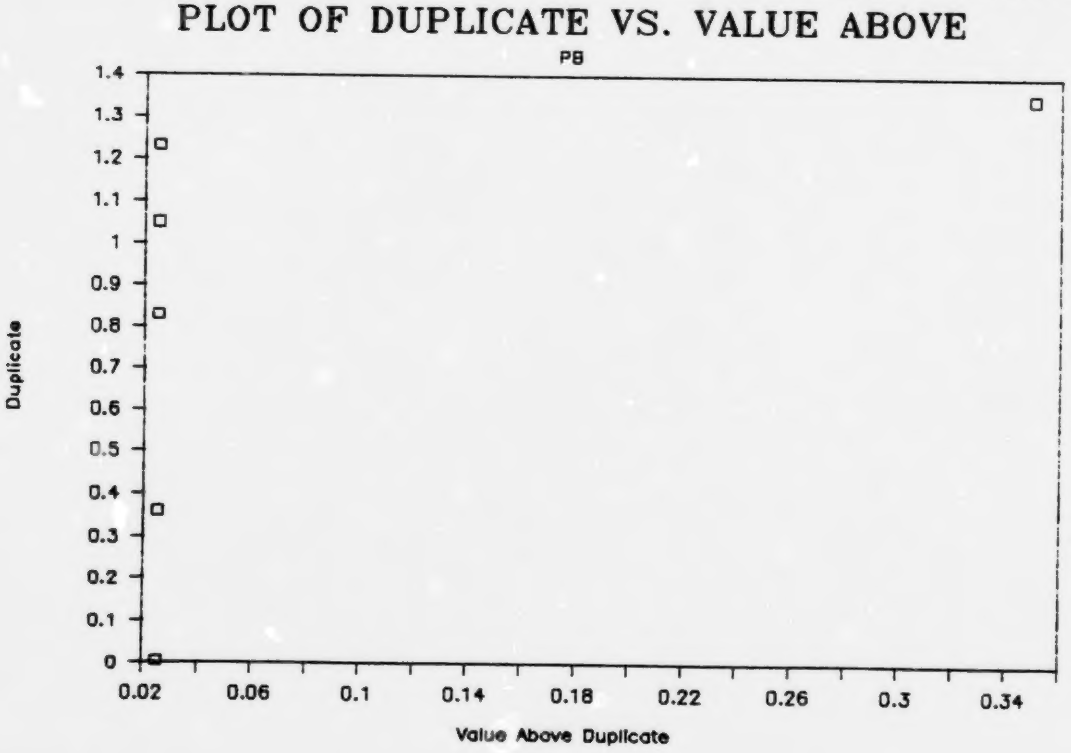


Fig. 5.7k Plot of Duplicate vs Value Above for Tailings Porewater - SI

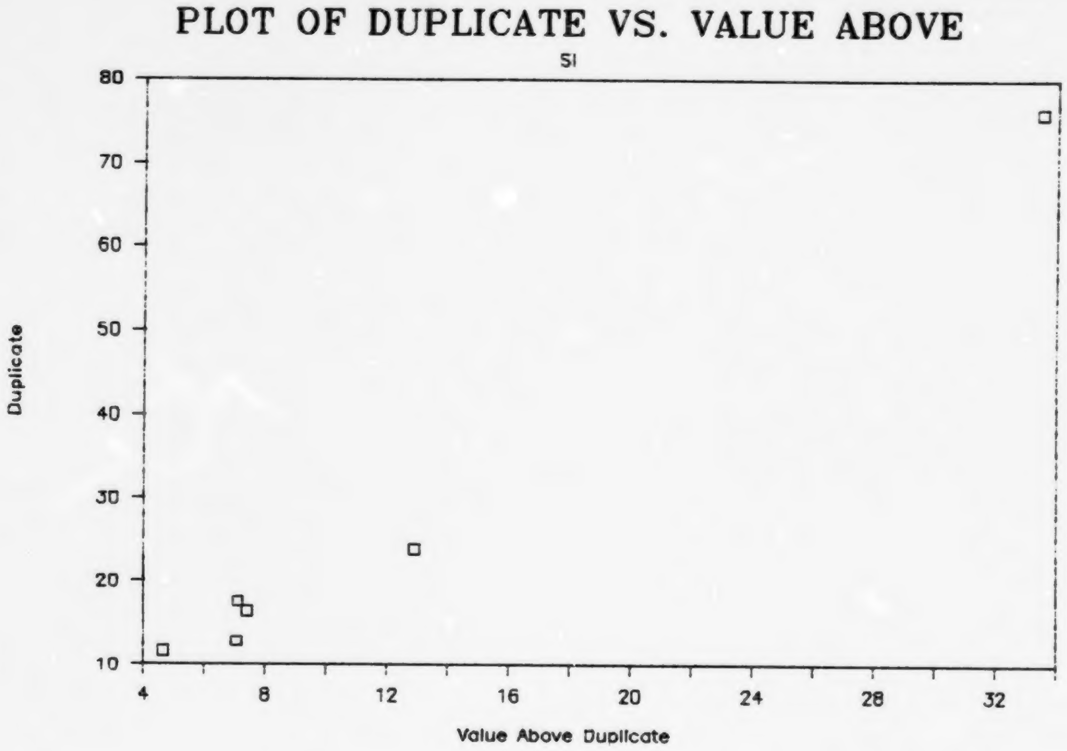


Fig. 5.71 Plot of Duplicate vs Value Above for Tailings Porewater - SR

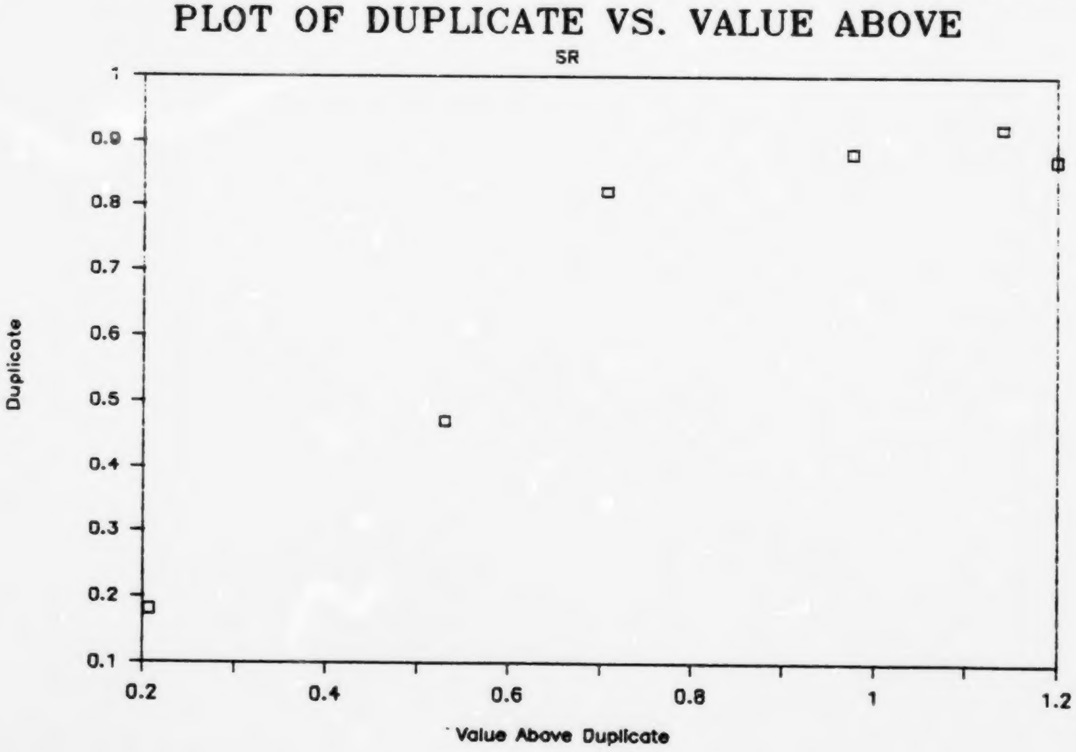


Fig. 5.7m Plot of Duplicate vs Value Above for Tailings Porewater - TI

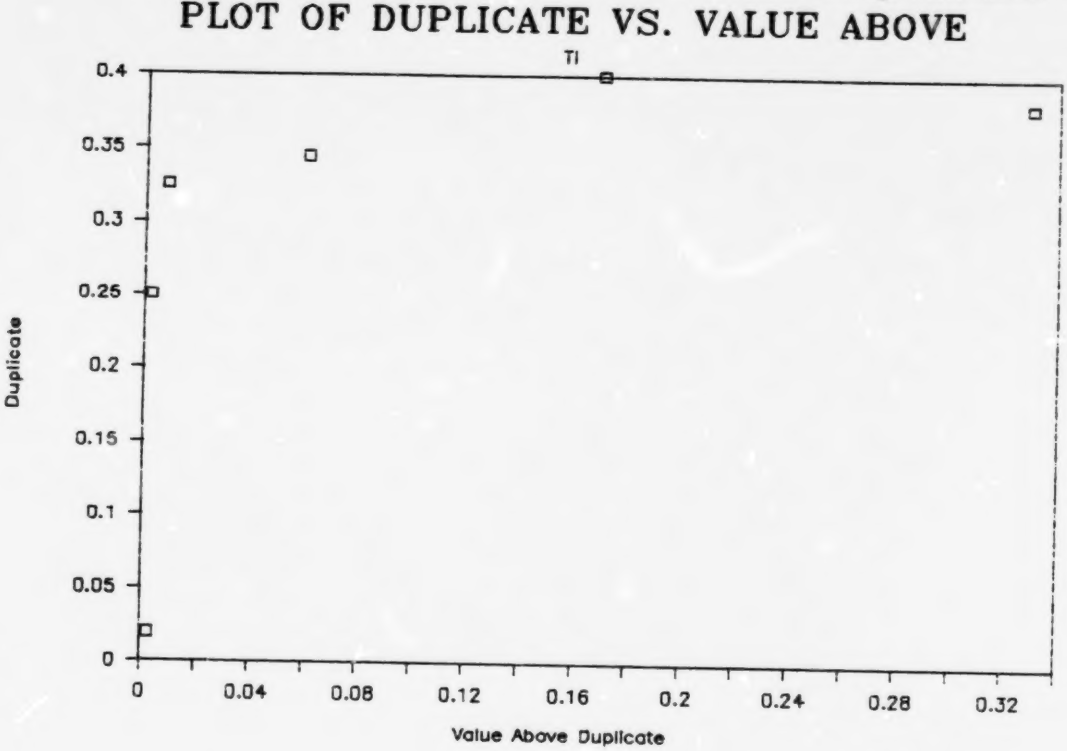


Fig. 5.7n Plot of Duplicate vs Value Above for Tailings Porewater - ZN

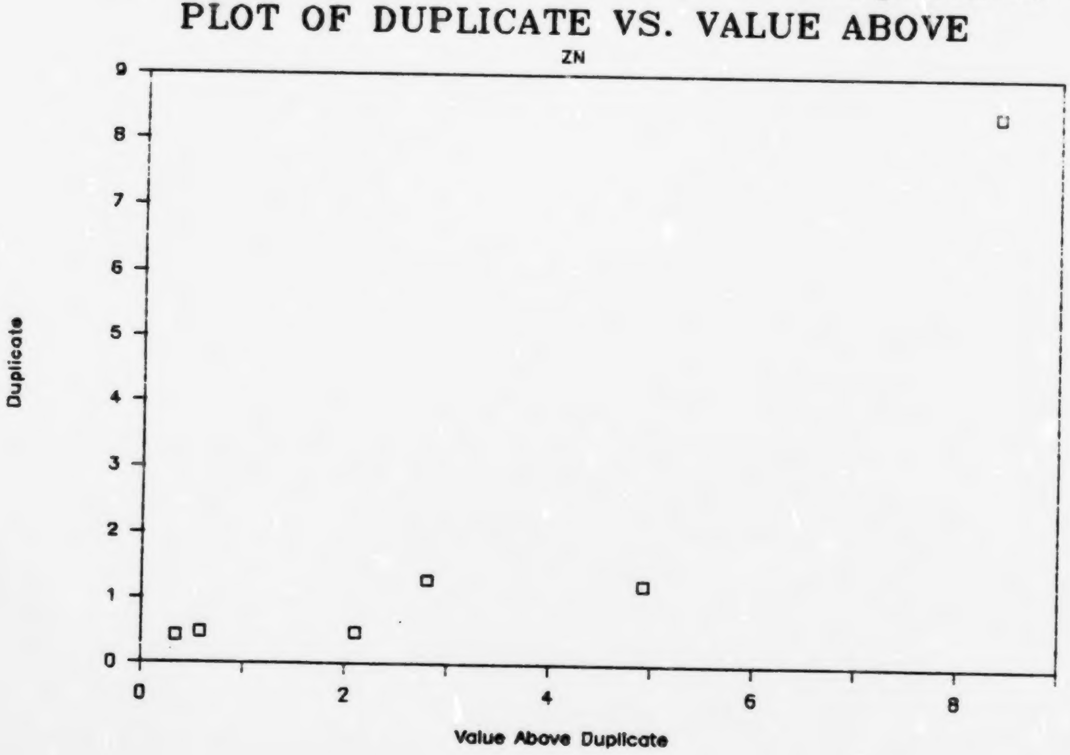


Fig. 5.7o Plot of Duplicate vs Value Above for Tailings Porewater - F-

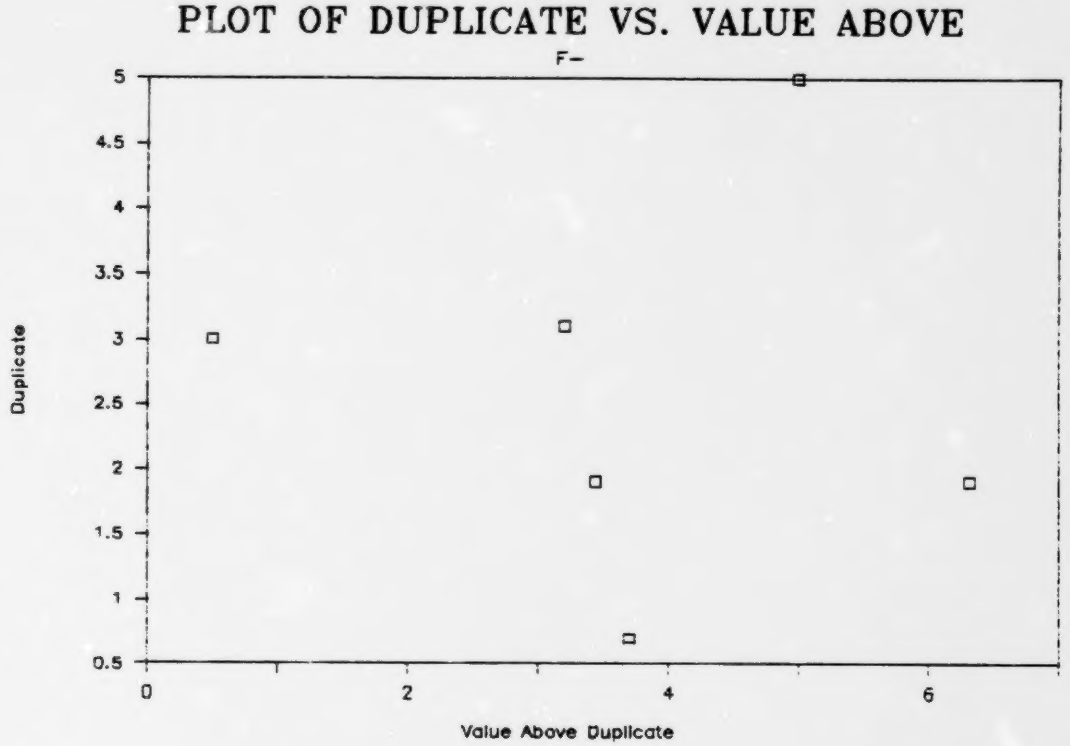


Fig. 5.7p Plot of Duplicate vs Value Above for Tailings Porewaer - CL-

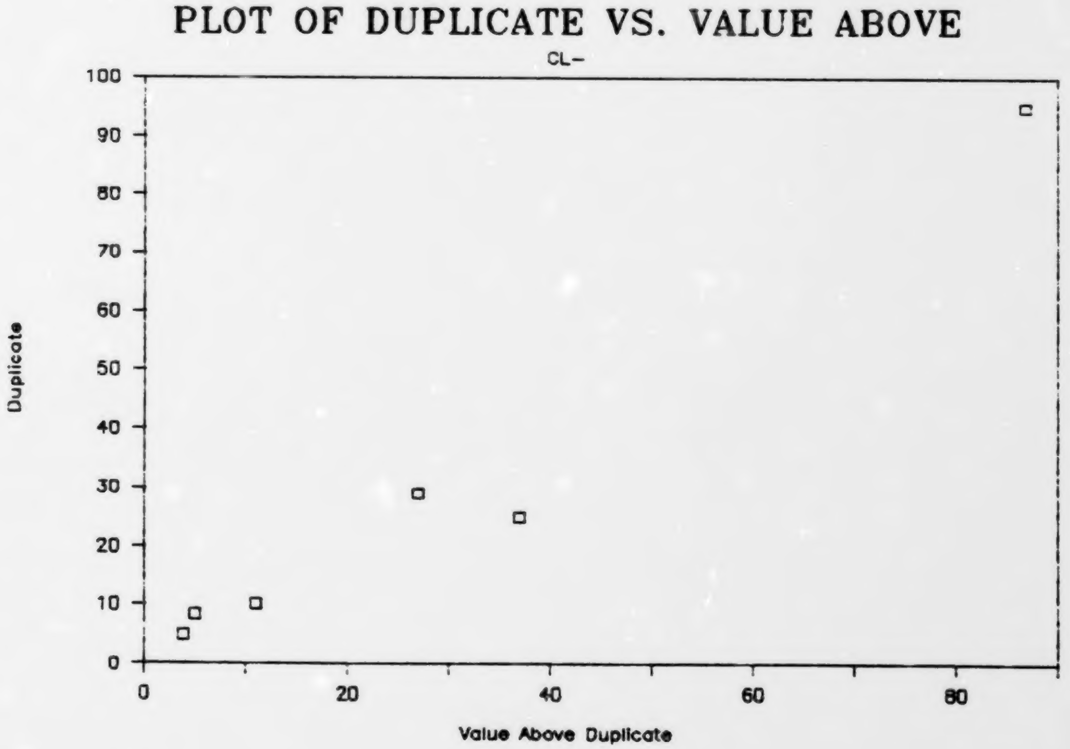


Fig. 5.7q Plot of Duplicate vs Value Above for Tailings Porewater - SO4=

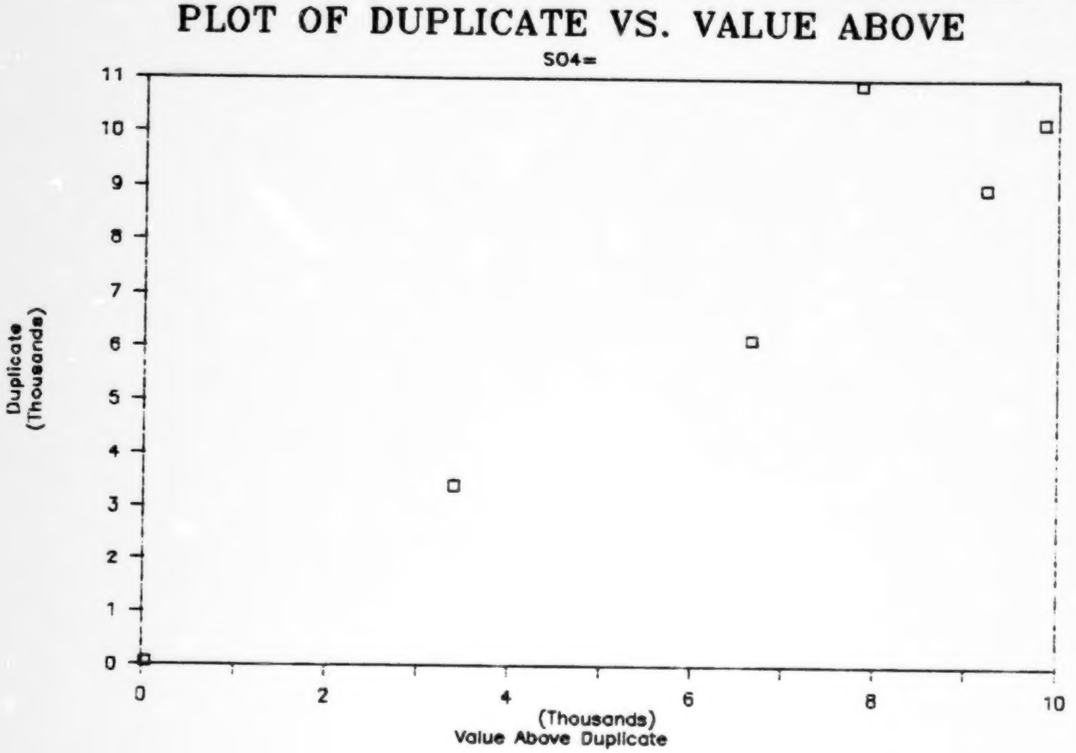


Fig. 5.7r Plot of Duplicate vs Value Above for Tailings Porewater - NH3

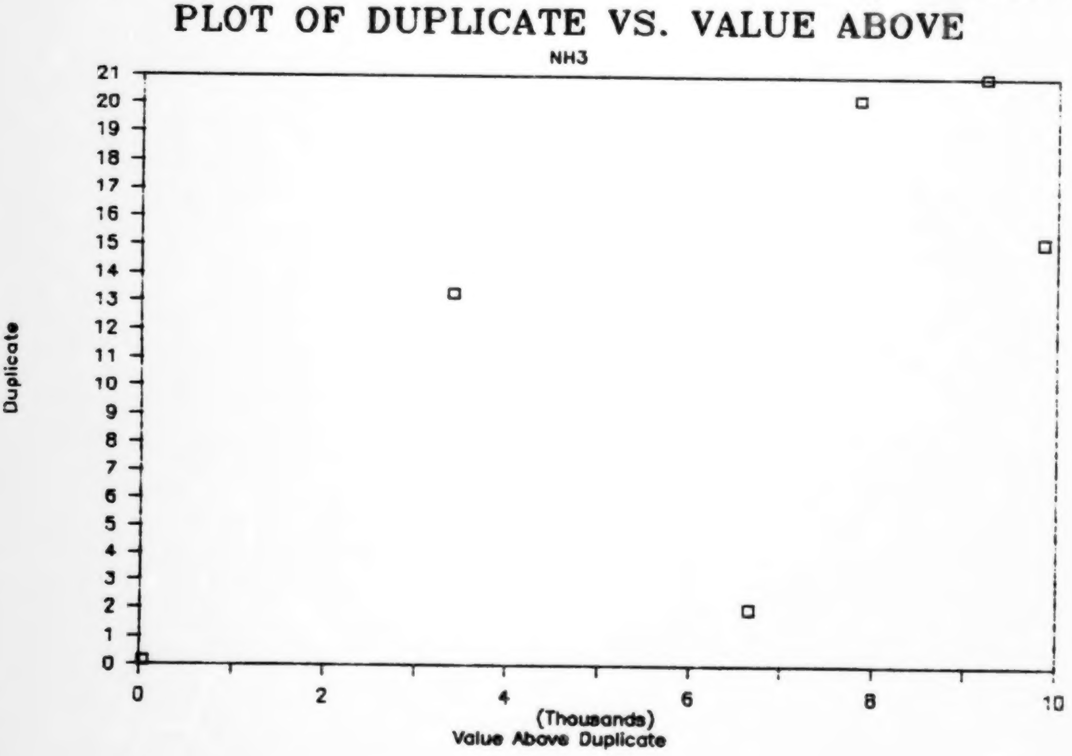


Fig. 5.7s Plot of Duplicate vs Value Above for Tailings Porewater - U

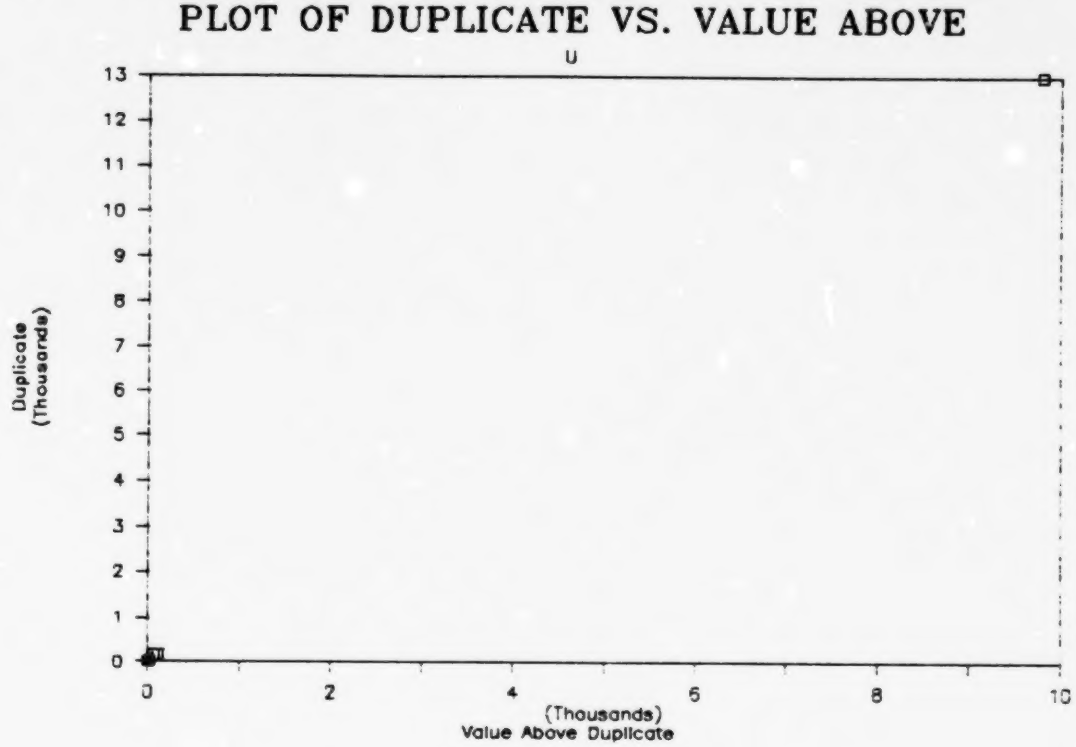


Fig. 5.7t Plot of Duplicate vs Value Above for Tailings Porewater - RA-226

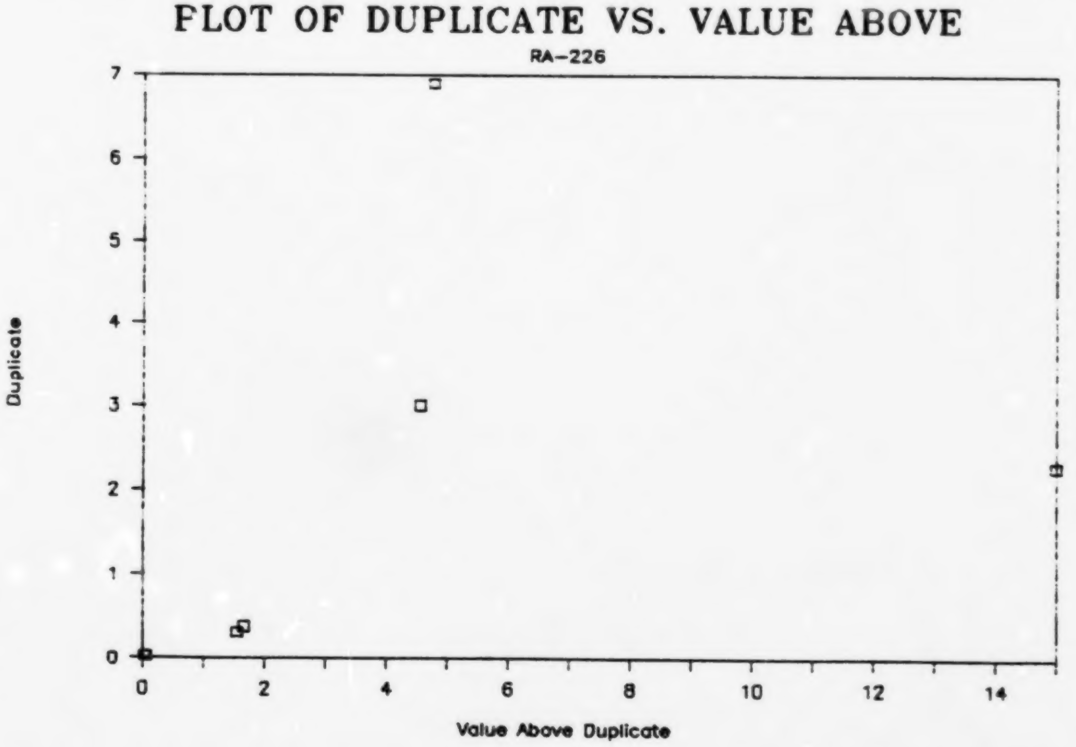


Fig. 5.7u Plot of Duplicate vs Value Above for Tailings Porewater - TH-230

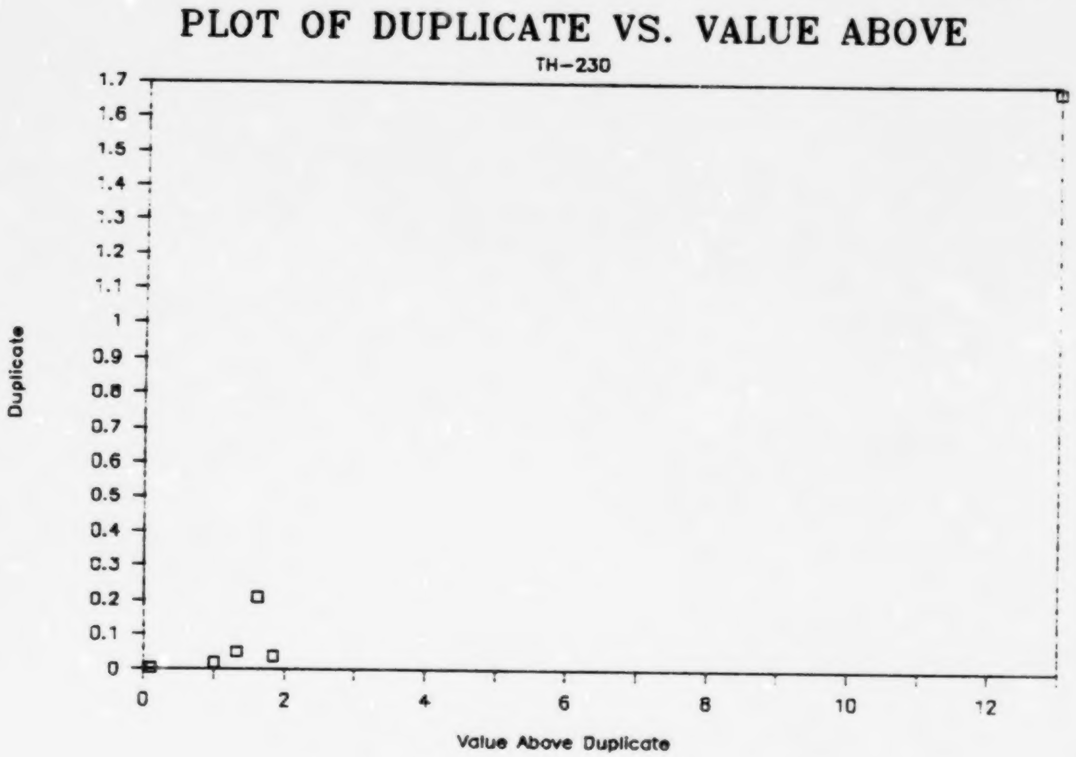
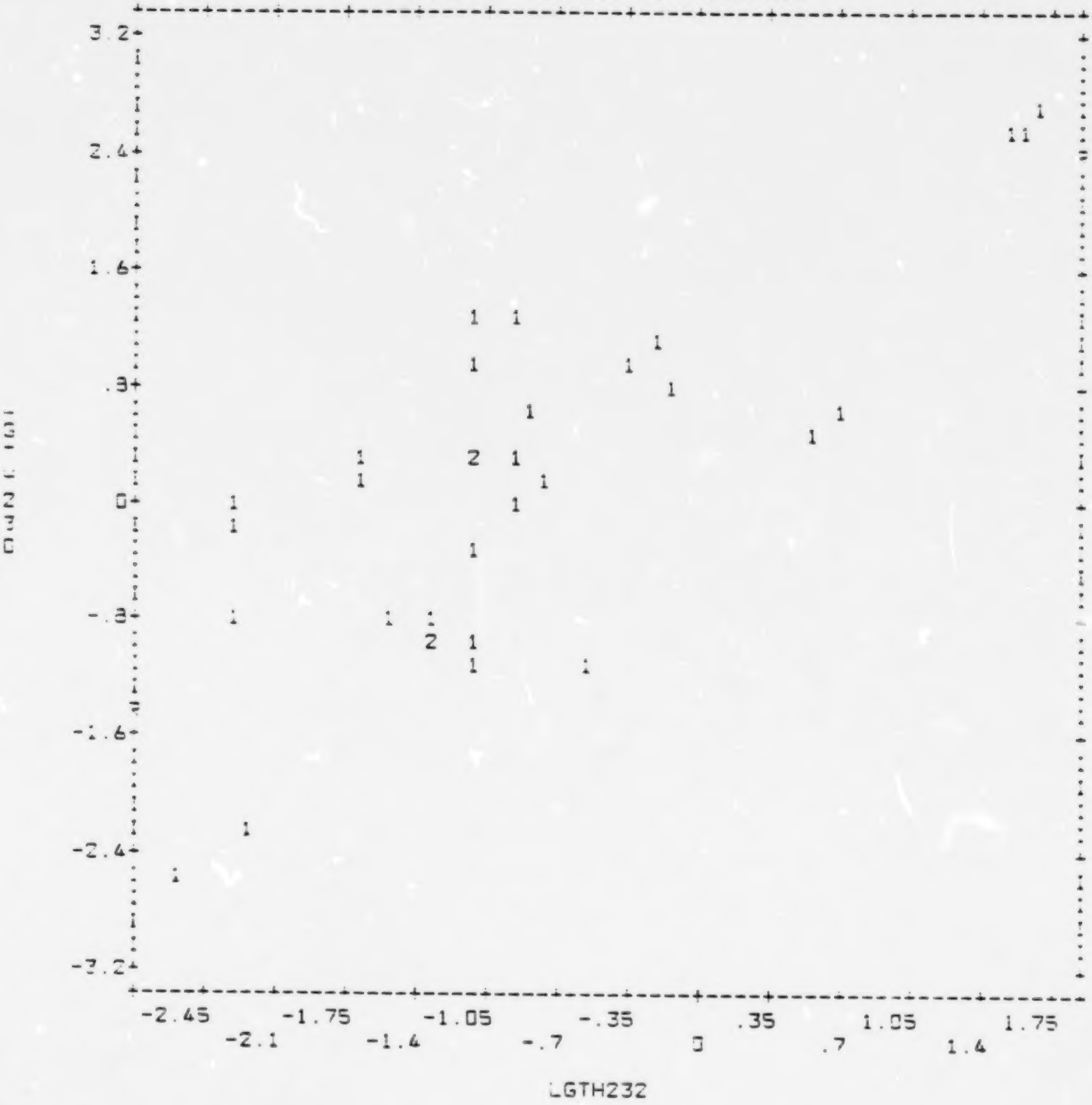


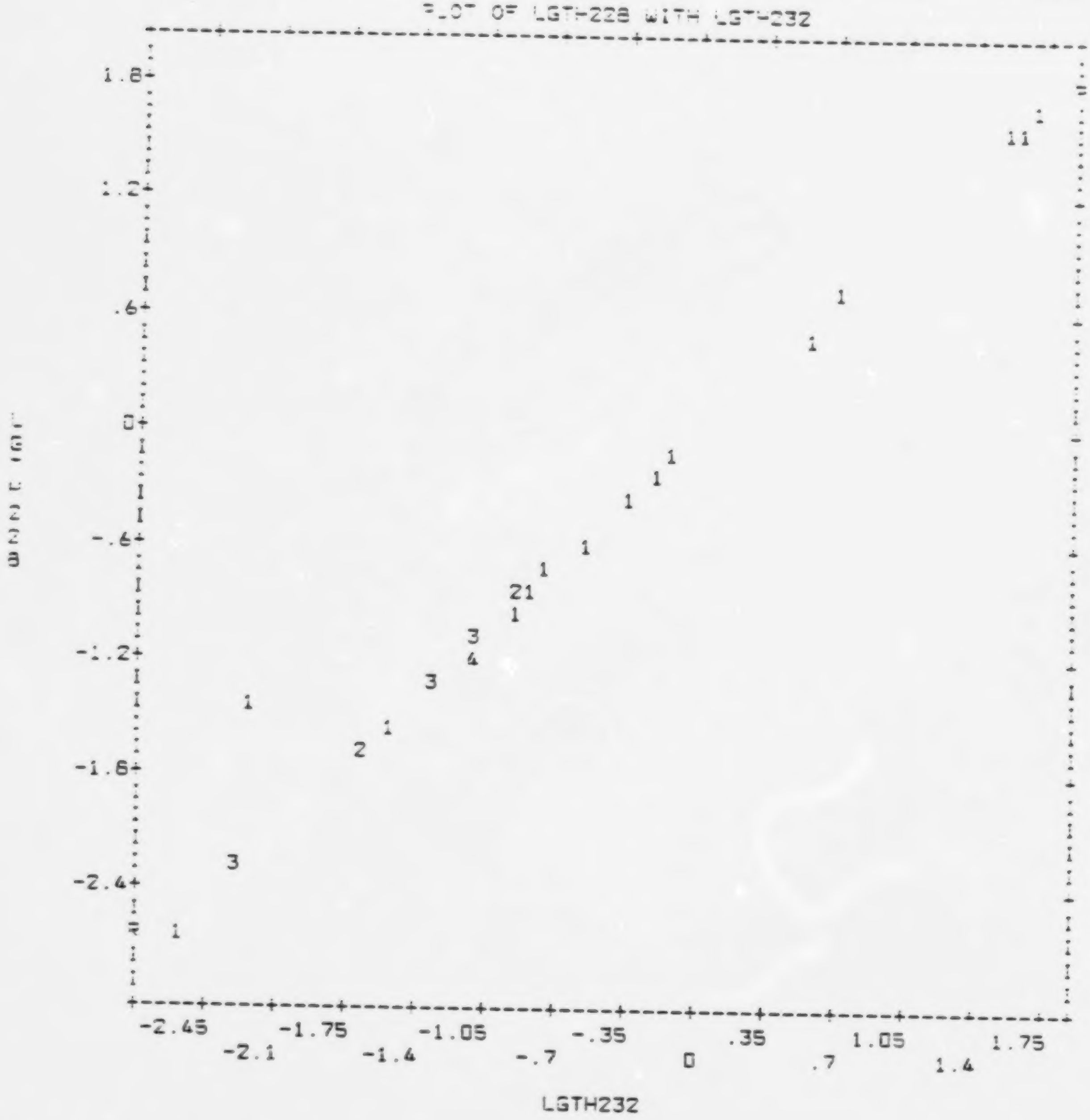
Fig. 5.8 Plot of Log (Th-230) Versus Log (Th-232) For Tailings Porewater for June

PLOT OF LGTH230 WITH LGTH232



```
32 cases plotted. Regression statistics of LGTH230 on LGTH232:
Correlation  .76478 R Squared  .58488  S.E. of Est     .80938 Sig.  .0000
Intercept(S.E )      .88969(   .18343)  Slope(S.E.)     .85436(    .13141)
```

Fig. 5.9 Plot of Log (Th-228) Versus Log (Th-232) for Tailings Porewater for June



```
32 cases plotted. Regression statistics of LGTH228 on LGTH232:
Correlation  .99232 R Squared  .98469  S.E. of Est      .13633 Sig.  .0000
Intercept(S.E.)      .00016(    .03090)  Slope(S.E.)      .97234(    .02213)
```

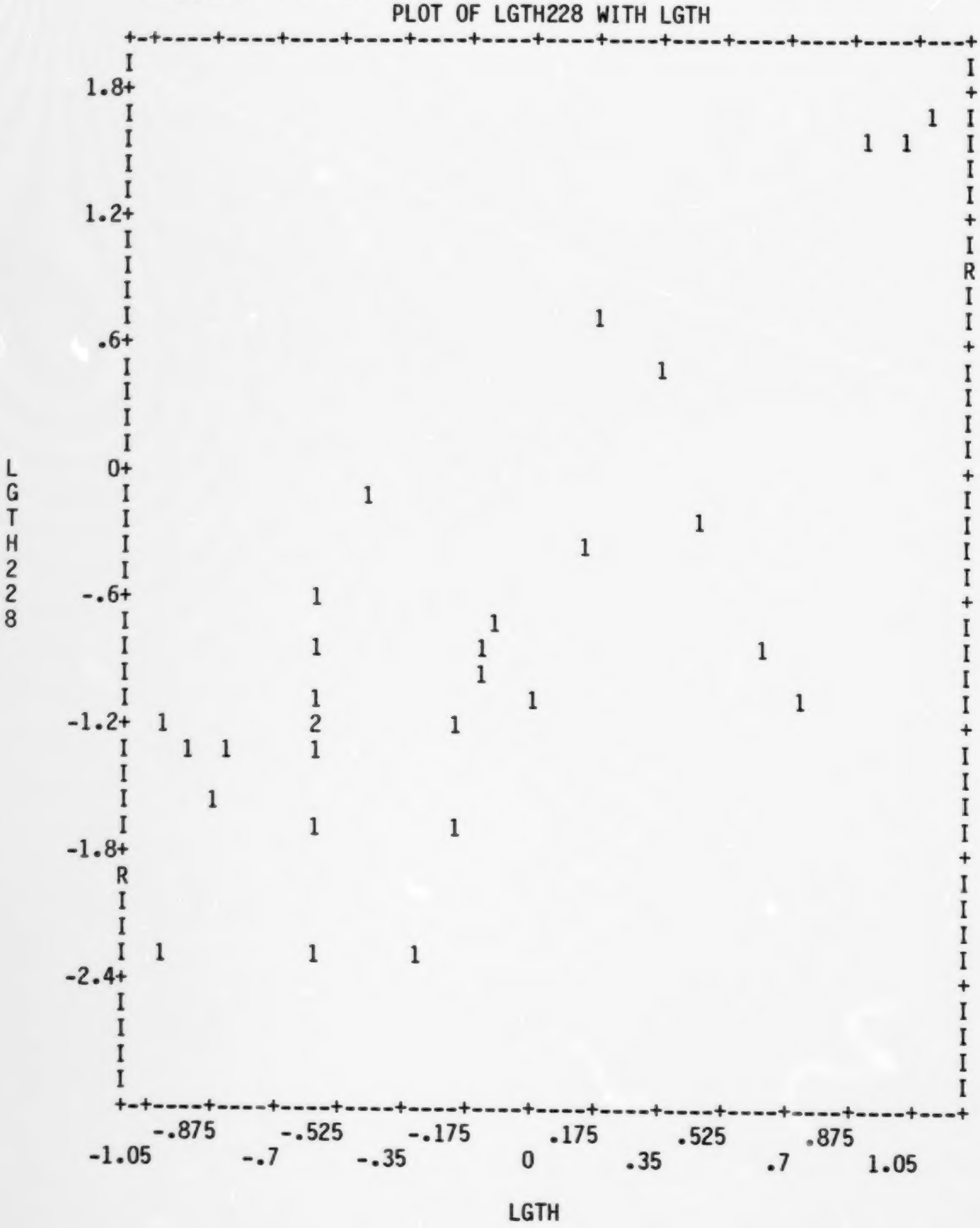
Fig. 5.10 Plot of Log (Th-230) Versus Log (Total Thorium) for Tailings Porewater for June

```
                             PLOT OF LGTH230 WITH LGTH
         +-+----+----+----+----+----+----+----+----+----+----+----+----+---+
      3.2+                                                                 +
         I                                                                 I
         I                                                                 I
         I                                                              1  I
         I                                                         1  1    I
      2.4+                                                                 R
         I                                                                 I
         I                                                                 I
         I                                                                 I
         I                                                                 I
      1.6+                                                                 +
         I                                                                 I
         I                                                 1  1            I
         I                                            1                    I
         I                               1   1                             I
       .8+                  1                                              +
L        I              1                     1                            I
G        I                                         1                       I
T        I              3            1                                     I
H        I                         1  1                                    I
2       0+                      1    1                                     +
3        I              1                                                  I
0        I                         1                                       I
         I                                                                 I
         I                                                                 I
      -.8+  1   1       1                                                  +
         I    1  1      1                                                  I
         R  1           1                                                  I
         I                                                                 I
         I                                                                 I
     -1.6+                                                                 +
         I                                                                 I
         I                                                                 I
         I                                                                 I
         I                                                                 I
     -2.4+                                                                 +
         I                                                                 I
         I                                                                 I
         I                                                                 I
         I                                                                 I
     -3.2+                                                                 +
         +-+----+----+----+----+----+----+----+----+----+----+----+----+---+
            -.875     -.525     -.175      .175      .525      .875
       -1.05       -.7      -.35         0       .35        .7      1.05

                                       LGTH

30 cases plotted. Regression statistics of LGTH230 on LGTH:
Correlation  .89103 R Squared   .79394  S.E. of Est     .49229 Sig.  .0000
Intercept(S.E.)      .60150(   .09398)  Slope(S.E.)    1.53519(   .14780)
```

Fig. 5.11 Plot of Log (Th-232) Versus Log (Total Thorium) for Tailings Porewater for June

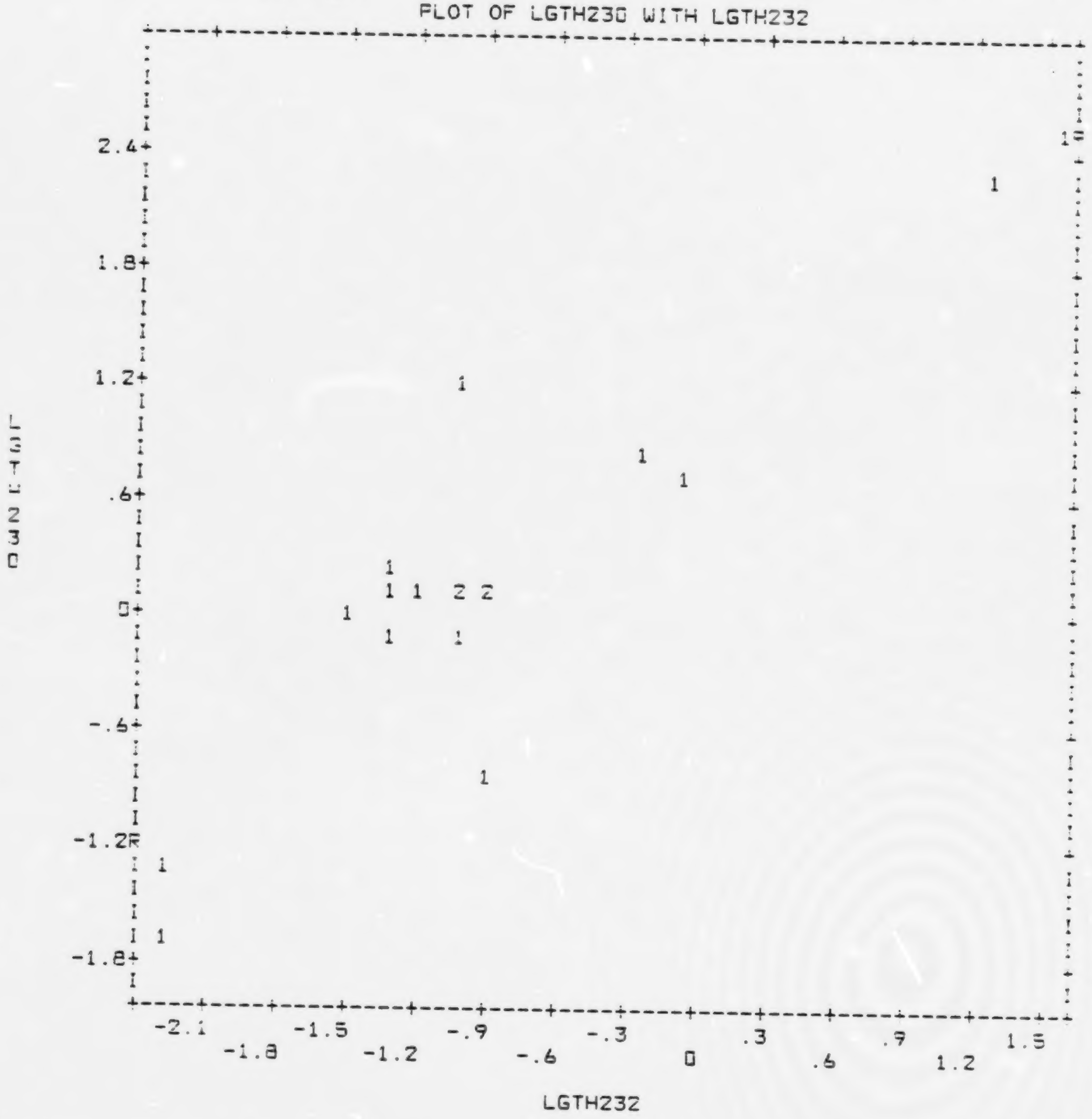
```
                      PLOT OF LGTH232 WITH LGTH
         +-+----+----+----+----+----+----+----+----+----+----+----+----+---+
         I                                                                 I
      1.8+                                                                 +
         I                                                              1  I
         I                                                         1  1    I
         I                                                                 I
         I                                                                 I
      1.2+                                                                 +
         I                                                                 I
         I                                                                 R
         I                                                                 I
         I                                    1                            I
       .6+                                                                 +
         I                                         1                       I
         I                                                                 I
         I                                                                 I
         I                                                                 I
L       0+                                                                 +
G        I                  1                                              I
T        I                                            1                    I
H        I                                   1                             I
2        I                                                                 I
3     -.6+              1                                                  +
2        I                            1                                    I
         I              1            1                     1               I
         I                           1                                     I
         I              1                1                    1            I
     -1.2+  1           2          1                                       +
         I    1  1      1                                                  I
         I                                                                 I
         I      1                                                          I
         I              1          1                                       I
     -1.8+                                                                 +
         R                                                                 I
         I                                                                 I
         I                                                                 I
         I  1           1       1                                          I
     -2.4+                                                                 +
         I                                                                 I
         I                                                                 I
         I                                                                 I
         I                                                                 I
         +-+----+----+----+----+----+----+----+----+----+----+----+----+---+
              -.875     -.525     -.175     .175      .525      .875
         -1.05      -.7       -.35       0        .35       .7       1.05

                                       LGTH

30 cases plotted. Regression statistics of LGTH232 on LGTH:
Correlation  .74784 R Squared  .55926  S.E. of Est     .71868 Sig.  .0000
Intercept(S.E.)    -.53208(   .13719)  Slope(S.E.)    1.28615(   .21577)
```

Fig. 5.12 Plot of Log (Th-228) Versus Log (Total Thorium) for Tailings Porewater for June



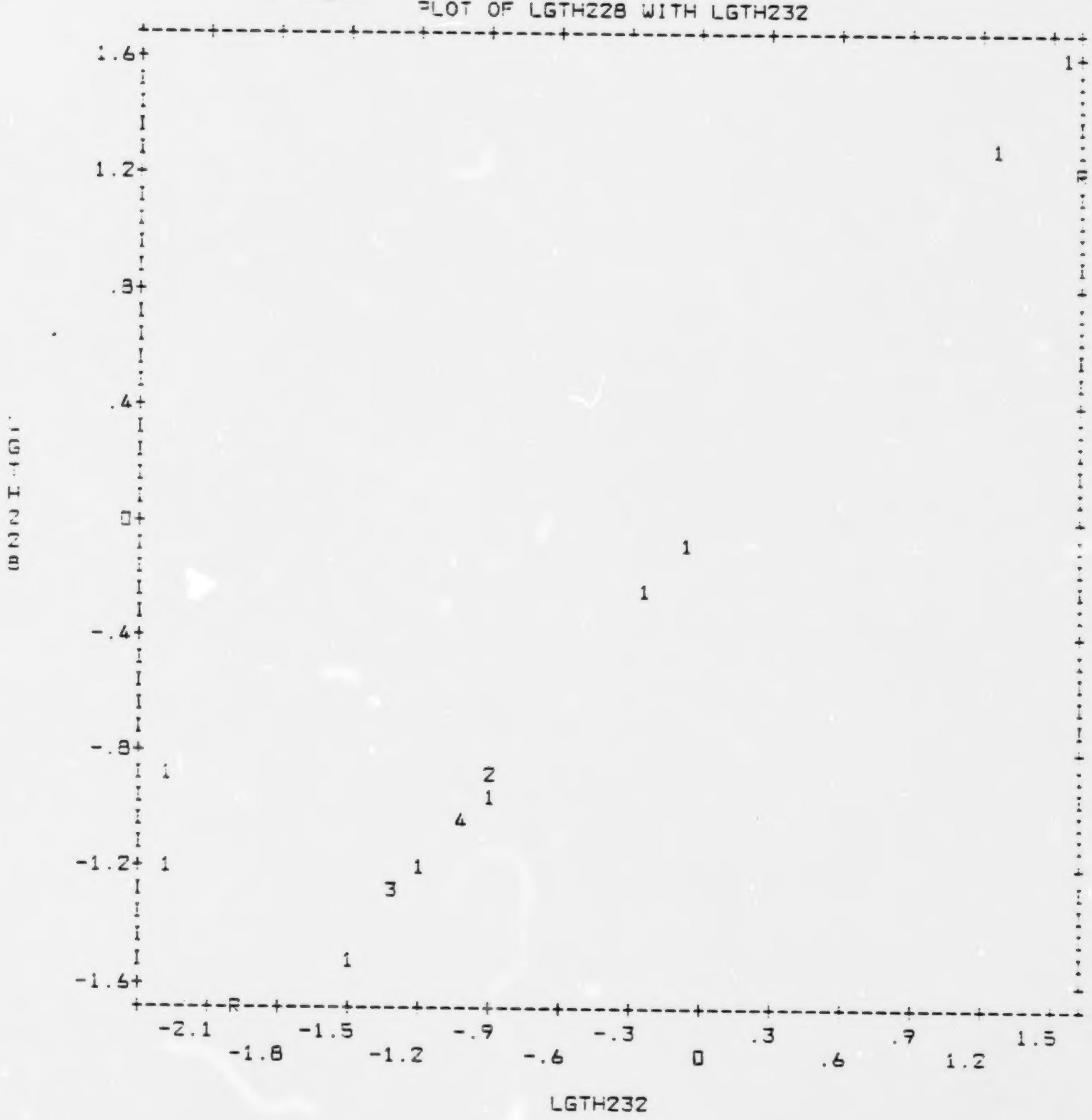
```
30 cases plotted. Regression statistics of LGTH228 on LGTH:
Correlation  .74784 R Squared  .55926  S.E. of Est     .71868 Sig.  .0000
Intercept(S.E.)    -.53208(   .13719)  Slope(S.E.)    1.28615(   .21577)
```

Fig. 5.13 Plot of Log (Th-230) Versus Log (Th-232) for Tailings Porewater for August



```
16 cases plotted. Regression statistics of LGTH230 on LGTH232:
Correlation  .90454 R Squared  .81819  S.E. of Est     .45980 Sig.  .0000
Intercept(S.E.)    1.07150(   .14535)  Slope(S.E.)      .94802(    .11172)
```

Fig. 5.14 Plot of Log (Th-228) Versus Log (Th-232) for Tailings Porewater for August



```
18 cases plotted. Regression statistics of LGTH228 on LGTH232:
Correlation  .91156 R Squared  .83095  S.E. of Est     .36481 Sig.  .0000
Intercept(S.E.)    -.04509(   .11532)  Slope(S.E.)     .78609(   .08864)
```

Table 5.12 Calculation of Anion - Cation Balance for Tailings Porewater
(a) June Readings (mev = milliequiv:)

ID		Al mev	Ca mev	Cu mev	Fe+2 mev	Fe+3 mev	K mev	Mg mev	Mn mev	Na mev	Ni mev	Sr mev	Th mev	Zn mev	H+ mev	d Cation mev	SO4- mev	d Anion mev	Cation/ Anion	Diff %
GW-01/A	ST-T	.58	23.	.25E-02	.15E+03	20.	3.6	14.	.60	1.3	.85E-02	.21E-01	.17E-01	.58E-01	.13E-02	.21E+03	180.	180.	1.18	16.70
GW-01/B	R	1.5	24.	.13E-02	.12E+03	15.	2.8	17.	.80	1.7	.85E-02	.26E-01	.43E-02	.84E-01	.13E-01	.16E+03	163.	163.	1.13	12.53
GW-01/E	T	7.8	24.	.13E-02	32.	2.4	.77	2.7	.11E-01	.22	.74E-01	.10E-01	.26E-01	.10	40.	.11E+03	86.0	86.0	1.28	24.30
GW-02/A	ST	.19	23.	.13E-02	68.	5.0	1.3	9.0	.47	.43	.85E-02	.16E-01	.43E-02	.52E-01	.32E-02	.11E+03	93.0	93.0	1.15	14.04
GW-02/B	T	4.0	22.	.54E-02	.17E+03	.36	4.1	19.	.55	2.2	.85E-02	.19E-01	.76E-01	.46E-01	.63E-02	.22E+03	203.	203.	1.09	8.48
GW-02/C	T	4.6	24.	.57E-02	58.	1.8	1.5	8.5	.91E-01	.22	.31E-01	.12E-01	.97E-01	.22	.18E-02	99.	80.3	80.3	1.24	21.04
GW-02/I	T	43.	22.	.31E-02	64.	4.3	1.5	6.2	.25E-01	.22	.55E-01	.12E-01	.48E-01	.26	.10E-01	.14E+03	138.	138.	1.03	2.82
GW-02/III	T	28.	24.	.13E-02	48.	2.9	1.3	5.8	.22E-01	.22	.37E-01	.14E-01	.24E-01	.80E-01	.71E-01	.11E+03	99.9	99.9	1.10	9.47
GW-02/IV	T	46.	23.	.13E-02	50.	5.7	1.8	5.2	.25E-01	.22	.61E-01	.87E-02	.40E-01	.76E-01	.11	.14E+03	133.	133.	1.06	5.37
GW-02/V	T	11.	23.	.13E-02	46.	4.5	1.5	3.5	.15E-01	.87	.37E-01	.82E-02	.18	.13	18.	.11E+03	115.	115.	.945	-5.61
GW-02/VI	T	29.	23.	.13E-02	56.	5.0	2.0	6.2	.22E-01	.22	.37E-01	.12E-01	.21	.11	5.0	.13E+03	126.	126.	1.00	.21
GW-02/VII	T	11.	24.	.13E-02	54.	4.7	1.3	2.9	.15E-01	.87	.41E-01	.75E-02	.14	.20	7.9	.11E+03	110.	110.	.969	-3.11
GW-04/A	ST	.56E-01	23.	.13E-02	48.	7.5	1.5	15.	.79	3.0	.85E-02	.22E-01	.14E-01	.73E-01	.16E-02	99.	84.9	84.9	1.17	15.70
GW-04/C	T	.54E-02	27.	.13E-02	2.0	.87	1.8	26.	.29	3.0	.85E-02	.19E-01	.12E-01	.12	.79E-04	61.	41.8	41.8	1.45	36.57
GW-04/E	T	.54E-02	26.	.13E-02	7.9	1.3	1.8	21.	.77	3.9	.85E-02	.19E-01	.43E-02	.64E-01	.20E-03	63.	48.9	48.9	1.30	25.88
GW-04/F	T	.56E-02	25.	.13E-02	7.9	.72E-01	1.8	28.	.38	6.5	.85E-02	.16E-01	.43E-02	.10	.40E-03	70.	55.8	55.8	1.26	22.86
GW-05/A	ST	.20	25.	.28E-02	.17E+03	16.	2.3	21.	.50	1.7	.85E-02	.27E-01	.10E-01	.64E-01	.79E-02	.24E+03	205.	205.	1.18	16.10
GW-05/B	R	.56E-03	6.1	.31E-03	.79	.00	.15	1.9	.46E-01	1.7	.20E-02	.64E-02	.45E-02	.12E-01	.25	11.	7.55	7.55	1.46	37.21
GW-05/C	ST	.56E-02	23.	.13E-02	.10E+03	10.	1.8	20.	.72	2.6	.85E-02	.29E-01	.43E-02	.52E-01	.40E-02	.16E+03	130.	130.	1.23	20.53
GW-05/D	T	.56E-02	22.	.35E-02	.22E+03	14.	.77	16.	.29	.43	.85E-02	.31E-01	.43E-02	.46E-01	.16	.28E+03	216.	216.	1.28	24.86
GW-05/F	T	.56E-02	22.	.31E-02	.17E+03	15.	.51	12.	.17	.43	.85E-02	.25E-01	.10E-01	.89E-01	.28	.22E+03	173.	173.	1.25	22.08
GW-05/F	T	.56E-02	22.	.28E-02	.14E+03	.00	1.0	7.9	.13	.22	.85E-02	.28E-01	.86E-02	.70E-01	.20E-02	.17E+03	143.	143.	1.20	18.54
GW-05/H	T	.56E-02	24.	.13E-02	36.	2.3	1.0	7.9	.21	.87	.85E-02	.16E-01	.43E-02	.11	.13E-02	72.	63.7	63.7	1.14	12.80
GW-05/I	T	.56E-01	22.	.13E-02	36.	9.5	1.3	36.	.44	.87	.85E-02	.13E-01	.16E-01	.86E-01	.63E-03	.11E+03	95.1	95.1	1.11	10.72
GW-05/J	T	4.9	21.	.13E-02	10.	3.2	.51	98.	.41	.43	.24E-01	.16E-01	.21E-01	.70E-01	.50E-01	.14E+03	124.	124.	1.12	11.59
GW-05/K	T	.24	24.	.13E-02	10.	.72E-01	.51	20.	.22	.43	.18	.10E-01	.12E-01	.86	.16E-01	56.	61.2	61.2	.922	-8.07
GW-06/B	R	.18E-01	1.2	.13E-03	.12	.00	.15	.69	.29E-02	.30	.85E-03	.33E-02	.17E-02	.36	.22E-03	2.8	.499	.499	5.68	140.12
GW-07/B	R	.17E-01	1.3	.13E-03	.29E-02	.00	.15	.75	.36E-03	.52	.85E-03	.71E-02	.17E-02	.31	.13E-04	3.1	.144	.144	21.4	182.13
GW-07/D	R	.78E-02	2.4	.13E-03	.44	.00	.23	1.3	.65E-01	.48	.72E-02	.36E-02	.22E-02	.17	.35E-02	5.2	3.39	3.39	1.52	41.51
GW-07/F	R	.78E-02	1.3	.13E-03	.18E-03	.00	.15	.82	.18E-02	.61	.85E-03	.47E-02	.19E-02	.15	.63E-04	3.0	.826	.826	3.67	114.29
GW-08/A	LAKE	.10E-01	.47	.28E-03	.18E-03	.00	.51E-01	.13	.18E-03	.13	.85E-03	.13E-02	.24E-02	.16	.79E-05	.96	.425	.425	[illegible]	77.52

Table 5.12 Calculation of Anion - Cation Balance for Tailings Porewater
(b) August Readings - using measured Fe (II) values
(mev = milliequiv.)

	ID	Al mev	Ca mev	Cu mev	Fe+2 mev	Fe+3 mev	K mev	Mg mev	Mn mev	Na mev	Ni mev	Sr mev	Th mev	Zn mev	H+ mev	d Cation mev	SO4- mev	d Anion mev	Cation/ Anion	Diff %
GW-01/B	R	.56E-03	21.	.13E-02	.12E+03	.31E+03	2.4	15.	.76	5.9	.85E-03	.31E-01	.43E-03	.14E-01	.25E-02	.48E+03	166.	166.	2.87	96.77
GW-01/F	T	2.8	26.	.13E-02	12.	36.	.20	1.3	.43E-01	.87E-01	.16E-01	.11E-01	.59E-02	.28E-01	7.9	86.	48.3	48.3	1.78	56.31
GW-02/C	T	5.8	22.	.59E-02	52.	.14E+03	1.4	7.5	.72E-01	.87E-01	.25E-01	.11E-01	.10	.20	1.3	.23E+03	88.0	88.0	2.59	88.68
GW-02/III	T	36.	21.	.12E-02	49.	.13E+03	1.4	5.0	.20E-01	.13	.34E-01	.13E-01	.16E-01	.21E-01	.25	.25E+03	110.	110.	2.26	77.15
GW-02/V	T	12.	22.	.10E-02	49.	.11E+03	1.5	2.7	.13E-01	.65	.36E-01	.81E-02	.14	.15E-01	40.	.24E+03	115.	115.	2.10	71.16
GW-02/VII	T	11.	22.	.10E-02	50.	.12E+03	1.4	2.8	.12E-01	.61	.43E-01	.94E-02	.88E-01	.19	40.	.25E+03	113.	113.	2.19	74.78
GW-03/B	T	.56E-03	23.	.13E-03	3.6	10.	1.6	37.	.33	4.3	.27E-02	.25E-01	.43E-03	.35E-01	.14E-03	81.	59.9	59.9	1.35	29.94
GW-03/D	T	.56E-03	24.	.13E-03	7.2	23.	2.3	37.	.38	9.0	.85E-03	.22E-01	.43E-03	.19E-01	.25E-03	.10E+03	64.5	64.5	1.59	45.59
GW-03/F	T	.56E-03	22.	.31E-03	11.	47.	2.1	31.	.42	5.6	.85E-03	.16E-01	.43E-03	.10E-01	.89E-03	.12E+03	70.8	70.8	1.69	51.14
GW-03/G	T	.56E-03	22.	.44E-03	13.	43.	2.3	28.	.34	7.9	.17E-02	.13E-01	.19E-02	.14E-01	.63E-03	.12E+03	69.1	69.1	1.69	51.40
GW-04/A	ST	.56E-03	21.	.85E-03	49.	.11E+03	1.6	14.	.73	3.6	.27E-02	.22E-01	.26E-02	.73E-02	.10E-01	.20E+03	88.9	88.9	2.24	76.64
GW-05/C	ST	.56E-03	21.	.12E-02	97.	.26E+03	1.8	18.	.66	2.3	.85E-03	.28E-01	.43E-03	.50E-02	.16E-02	.40E+03	142.	142.	2.78	94.30
GW-05/E	T	.56E-03	20.	.21E-02	.16E+03	.41E+03	.41	11.	.16	.35	.85E-03	.22E-01	.19E-02	.17E-01	.11E-02	.60E+03	192.	192.	3.12	102.88
GW-05/F	T	.56E-03	20.	.16E-02	.11E+03	.30E+03	.95	6.5	.11	.30	.85E-03	.26E-01	.22E-02	.41E-01	.10E-02	.43E+03	140.	140.	3.08	101.93
GW-05/H	T	.56E-03	23.	.66E-03	35.	83.	1.2	8.1	.72	.91	.85E-03	.17E-01	.16E-02	.18E-01	.63E-03	.15E+03	64.5	64.5	2.34	80.37
GW-05/I	T	.56E-03	21.	.66E-03	41.	.11E+03	1.1	32.	.46	.78	.85E-03	[illegible]	.43E-03	.19E-01	.16E-02	.20E+03	92.4	92.4	2.22	75.70

Table 5.12 Calculation of Anion - Cation Balance for Tailings Porewater
(c) August Readings - using total iron values
(mev = milliequiv.)

	ID	Al mev	Ca mev	Cu mev	Fe+2 mev	Fe+3 mev	K mev	Mg mev	Mn mev	Na mev	Ni mev	Sr mev	Th mev	Zn mev	H+ mev	d Cation mev	SO4- mev	d Anion mev	Cation/ Anion	Diff %
GW-01/B	R	.56E-03	21.	.13E-02	.12E+03	.00	2.4	15.	.76	5.9	.85E-03	.31E-01	.43E-03	.14E-01	.25E-02	.17E+03	166.	166.	1.01	1.13
GW-01/F	T	2.8	26.	.13E-02	12.	.00	.20	1.3	.43E-01	.87E-01	.16E-01	.11E-01	.59E-02	.28E-01	7.9	50.	48.3	48.3	1.05	4.48
GW-02/C	T	5.8	22.	.59E-02	52.	.00	1.4	7.5	.72E-01	.87E-01	.25E-01	.11E-01	.10	.20	1.3	90.	88.0	88.0	1.03	2.68
GW-02/III	T	36.	21.	.12E-02	49.	.00	1.4	5.0	.20E-01	.13	.34E-01	.13E-01	.16E-01	.21E-01	.25	.11E+03	110.	110.	1.03	2.78
GW-02/V	T	17.	22.	.10E-02	49.	.00	1.5	2.7	.13E-01	.55	.36E-01	.81E-02	.14	.15E-01	40.	.13E+03	115.	115.	1.11	10.05
GW-02/VII	T	11.	22.	.18E-02	50.	.00	1.4	2.8	.12E-01	.61	.43E-01	.94E-02	.88E-01	.19	40.	.13E+03	113.	113.	1.13	12.35
GW-03/B	T	.56E-03	23.	.13E-03	3.6	.00	1.6	37.	.33	4.3	.27E-02	.25E-01	.43E-03	.35E-01	.14E-03	71.	59.9	59.9	1.18	16.42
GW-03/D	T	.56E-03	24.	.13E-03	7.2	.00	2.3	37.	.38	9.0	.85E-03	.22E-01	.43E-03	.19E-01	.25E-03	80.	64.5	64.5	1.24	21.18
GW-03/F	T	.56E-03	22.	.31E-03	11.	.00	2.1	31.	.42	5.6	.85E-03	.16E-01	.43E-03	.10E-01	.89E-03	72.	70.8	70.8	1.02	2.23
GW-03/H	T	.56E-03	22.	.44E-03	13.	.00	2.3	28.	.34	7.9	.17E-02	.15E-01	.19E-02	.14E-01	.63E-03	74.	69.1	69.1	1.07	6.41
GW-04/A	ST	.56E-03	21.	.85E-03	49.	.00	1.6	14.	.73	3.6	.27E-02	.22E-01	.26E-02	.73E-02	.10E-01	90.	88.9	88.9	1.01	1.32
GW-05/C	ST	.56E-03	21.	.12E-02	97.	.00	1.8	18.	.66	2.3	.85E-03	.28E-01	.43E-03	.58E-02	.16E-02	.14E+03	142.	142.	.988	-1.23
GW-05/F	T	.56E-03	20.	.21E-02	.16E+03	.00	.41	11.	.16	.35	.85E-03	.22E-01	.19E-02	.17E-01	.11E-02	.19E+03	192.	192.	.983	-1.71
GW-05/F	T	.56E-03	20.	.16E-02	.11E+03	.00	.95	6.5	.11	.30	.85E-03	.26E-01	.22E-02	.41E-01	.10E-02	.14E+03	140.	140.	.973	-2.78
GW-05/H	T	.56E-03	23.	.66E-03	35.	.00	1.2	8.1	.22	.91	.85E-03	.17E-01	.16E-02	.18E-01	.63E-03	68.	64.5	64.5	1.05	4.91
GW-05/I	T	.56E-03	21.	.66E-03	41.	.00	1.1	32.	.46	.78	.85E-03	.13E-01	.43E-03	.19E-01	.16E-02	96.	92.4	92.4	1.04	4.29

Table 5.13 Calculation of Anion - Cation Balance for Surface Water Samples
(a) Station SW-01 (mev = milliequiv.)

ID	Al mev	Ca mev	Cu mev	Fe+2 mev	Fe+3 mev	K mev	Mg mev	Mn mev	Na mev	Ni mev	Sr mev	Th mev	Zn mev	H+ mev	d Cation mev	SO4- mev	d Anion mev	Cation/ Anion	Diff %
SW01FEB10-22	2.2	15.	.35E-02	28.	.72	.41	4.4	.13	.45	.92E-02	.96E-02	.57E-02	.61E-02	.16	52.	65.	65.	.80	-21.72
SW01MAR12	2.2	11.	.69E-02	16.	2.0	.26	2.0	.76E-01	.30	.70E-02	.61E-02	.57E-02	.51E-02	.22	34.	17.	17.	2.1	69.40
SW01MAR18	2.4	14.	.25E-02	21.	1.1	.34	3.7	.87E-01	.40	.78E-02	.84E-02	.57E-02	.55E-02	.18	44.	44.	44.	1.0	.78
SW01MAR21	2.1	11.	.31E-02	22.	.61	.32	3.3	.80E-01	.38	.65E-02	.71E-02	.57E-02	.75E-02	1.0	41.	39.	39.	1.0	4.44
SW01MAR25	2.0	11.	.49E-02	19.	.68	.27	3.0	.71E-01	.33	.65E-02	.66E-02	.57E-02	.72E-02	.32	37.	17.	17.	2.2	74.04
SW01MAR29	1.5	5.1	.60E-02	6.1	.00	.11	1.3	.29E-01	.15	.41E-02	.30E-02	.57E-02	.52E-02	.56	15.	17.	17.	.87	-13.99
SW01 03/04UN	3.3	11.	.40E-02	14.	.00	.15	2.7	.62E-01	.13	.72E-02	.66E-02	.47E-02	.46E-02	.45	32.	31.	31.	1.0	3.09
APR18SW01UNF	1.0	5.4	.36E-02	3.4	.00	.77E-01	1.0	.19E-01	.87E-01	.44E-02	.25E-02	.33E-02	.31E-02	.63	13.	12.	12.	1.1	5.21
APR22SW01UNF	2.0	6.6	.42E-02	2.0	.63	.51E-01	.99	.18E-01	.43E-01	.40E-02	.26E-02	.33E-02	.31E-02	.00	12.	12.	12.	1.0	-.18
SW01 25/04UN	3.1	8.6	.63E-02	4.0	.79	.77E-01	1.5	.31E-01	.87E-01	.60E-02	.41E-02	.67E-02	.46E-02	.71	19.	33.	33.	.58	-53.11
SW01 26/04UN	3.6	10.	.67E-02	4.7	1.4	.10	1.0	.35E-01	.13	.82E-02	.48E-02	.79E-02	.46E-02	.79	22.	23.	23.	.96	-3.87
SW01 29/04UN	4.3	12.	.70E-02	7.4	.86	.13	2.2	.44E-01	.13	.99E-02	.60E-02	.95E-02	.58E-02	1.1	29.	28.	28.	1.0	2.33
MAY02SW01UNF	4.1	13.	.63E-02	9.5	.00	.15	2.4	.46E-01	.13	.10E-01	.57E-02	.69E-02	.67E-02	.00	29.	32.	32.	.90	-10.25
MAY06SW01UNF	3.4	12.	.51E-02	7.6	.57	.13	1.9	.37E-01	.13	.85E-02	.47E-02	.67E-02	.58E-02	.35	26.	27.	27.	.97	-2.09
MAY09SW01UNF	3.7	13.	.52E-02	8.9	.64	.13	2.1	.43E-01	.13	.92E-02	.57E-02	.59E-02	.58E-02	.00	28.	31.	31.	.92	-8.25
MAY13SW01UNF	3.7	14.	.52E-02	9.7	.64	.15	2.3	.44E-01	.13	.89E-02	.57E-02	.57E-02	.55E-02	.40	31.	32.	32.	.95	-5.13
MAY22SW01UNF	3.5	16.	.41E-02	12.	.43	.15	2.5	.40E-01	.13	.89E-02	.62E-02	.40E-02	.52E-02	.00	34.	34.	34.	1.0	.51
SW01 JN10-19	3.2	17.	.32E-02	12.	.29	.15	2.8	.52E-01	.13	.72E-02	.67E-02	.76E-02	.40E-02	.45	36.	37.	37.	.99	-1.12
SW01 JN27-05	2.9	19.	.19E-02	17.	.00	.18	3.5	.67E-01	.17	.60E-02	.77E-02	.60E-02	.40E-02	.40	43.	42.	42.	1.0	1.92
SW-01-JUL.11	3.0	20.	.16E-02	21.	1.4	.26	4.3	.89E-01	.22	.72E-02	.90E-02	.67E-02	.43E-02	.50	51.	47.	47.	1.1	7.38
SW-01-JUL.25	3.5	15.	.62E-02	13.	6.6	.23	3.7	.82E-01	.17	.75E-02	.76E-02	.15E-01	.46E-02	.35	43.	42.	42.	1.0	2.42
SW-01-JUL.31	3.4	16.	.61E-02	20.	.00	.23	3.7	.81E-01	.22	.75E-02	.75E-02	.16E-01	.46E-02	.79	44.	43.	43.	1.0	3.73

Table 5.13 Calculation of Anion - Cation Balance for Surface Water Samples
(b) Station SW-02 (mev = milliequiv.)

ID	Al mev	Ca mev	Cu mev	Fe+2 mev	Fe+3 mev	K mev	Mg mev	Mn mev	Na mev	Ni mev	Sr mev	Th mev	Zn mev	H+ mev	d Cation mev	SO4- mev	d Anion mev	Cation/ Anion	Diff %
SW02JAN23	1.58	19.	.19E-02	23.	37.	1.2	13.	.62	1.8	.11E-01	.18E-02	.52E-02	.49E-02	.63	98.	.11E+03	.11E+03	.91	-9.41
SW02MAR12	1.29	14.	.13E-02	40.	3.4	.77	9.1	.38	1.3	.75E-02	.14E-01	.52E-02	.40E-02	.45	71.	65.	65.	1.1	9.27
SW02MAR18	1.40	17.	.13E-02	50.	.00	.95	11.	.43	1.6	.85E-02	.16E-01	.52E-02	.37E-02	.35	83.	81.	81.	1.0	1.95
SW02MAR25	1.33	16.	.17E-02	43.	3.2	.87	10.	.37	1.5	.87E-02	.15E-01	.52E-02	.49E-02	.71	77.	71.	71.	1.1	8.44
SW02MAR29	1.11	11.	.19E-02	30.	1.4	.61	6.9	.26	1.0	.75E-02	.10E-01	.52E-02	.54E-02	.40	53.	50.	50.	1.1	5.57
SW02 03/04AM	2.00	14.	.29E-02	32.	1.5	.59	8.0	.28	.96	.82E-02	.13E-01	.59E-02	.40E-02	.63	60.	61.	61.	.98	-1.63
APR22SW02UNF	1.11	5.8	.18E-02	9.6	.00	.23	2.7	.90E-01	.35	.40E-02	.42E-02	.33E-02	.34E-02	.63	21.	20.	20.	1.0	1.64
SW02 25/04AM	1.44	12.	.19E-02	8.0	20.	.53	6.8	.24	.82	.58E-02	.86E-02	.52E-02	.32E-02	.63	51.	20.	20.	2.6	[illegible].76
SW02 29/04AM	1.12	5.1	.23E-02	5.3	.14	.18	1.9	.59E-01	.26	.37E-02	.34E-02	.53E-02	.21E-02	1.1	15.	15.	15.	1.0	3.36
MAY02SW02UNF	1.14	5.5	.20E-02	6.2	.00	.18	2.0	.63E-01	.26	.44E-02	.32E-02	.31E-02	.28E-02	1.0	16.	16.	16.	1.0	-.28
MAY06SW02UNF	1.20	5.9	.21E-02	5.2	.79	.20	2.2	.66E-01	.26	.44E-02	.34E-02	.41E-02	.21E-02	.71	16.	17.	17.	.97	-2.97
MAY09SW02UNF	1.29	6.4	.21E-02	5.2	1.2	.20	2.1	.69E-01	.26	.40E-02	.35E-02	.45E-02	.24E-02	.63	17.	19.	19.	.94	-6.27
MAY13SW02UNF	1.46	7.4	.24E-02	6.0	1.6	.23	2.7	.83E-01	.30	.51E-02	.43E-02	.50E-02	.28E-02	.79	21.	21.	21.	.99	-1.22
MAY22SW02UNF	1.59	8.8	.25E-02	8.0	1.8	.28	3.3	.11	.39	.58E-02	.52E-02	.50E-02	.28E-02	1.0	25.	25.	25.	1.0	1.67
SW02 JU10-19	2.03	13.	.24E-02	18.	1.9	.43	5.9	.18	.61	.51E-02	.85E-02	.81E-02	.31E-02	1.2	44.	44.	44.	.98	-1.82
SW02 JU27-05	2.02	19.	.18E-02	37.	4.3	.79	10.	.36	1.1	.40E-02	.14E-01	.69E-02	.34E-02	.71	76.	75.	75.	1.0	1.04
SW-02-JUL.11	1.97	20.	.17E-02	47.	2.5	.90	11.	.41	1.3	.44E-02	.16E-01	.71E-02	.34E-02	.89	87.	84.	84.	1.0	3.56
SW-02-JUL.25	1.88	18.	.19E-02	28.	14.	.72	10.	.36	1.2	.44E-02	.14E-01	.74E-02	.28E-02	1.1	76.	73.	73.	1.0	3.40
SW-02-JUL.31	1.84	18.	.18E-02	41.	.00	.69	10.	.35	1.1	.41E-02	.13E-01	.69E-02	.28E-02	.71	73.	73.	73.	1.0	-.23

Table 5.13 Calculation of Anion - Cation Balance for Surface Water Samples
(c) Station SW-03 (mev = milliequiv.)

ID	Al mev	Ca mev	Cu mev	Fe+2 mev	Fe+3 mev	K mev	Mg mev	Mn mev	Na mev	Ni mev	Sr mev	Th mev	Zn mev	H+ mev	d Cation mev	SO4- mev	d Anion mev	Cation/ Anion	Diff %
SW03MAR03	.90	3.0	.16E-02	3.3	.00	.87E-01	1.5	.44E-01	.19	.34E-03	.21E-02	.25E-02	.18E-02	1.3	10.	11.	11.	.96	-4.26
SW03MAR12	1.4	4.2	.22E-02	1.3	4.0	.12	2.1	.62E-01	.27	.51E-02	.27E-02	.25E-02	.21E-02	1.1	15.	16.	16.	.90	-10.71
SW03MAR18	1.4	4.3	.19E-02	.54	4.5	.12	2.1	.56E-01	.25	.44E-02	.27E-02	.25E-02	.21E-02	.89	14.	17.	17.	.85	-16.03
SW03MAR21	1.0	3.3	.22E-02	.36	4.1	.12	1.8	.51E-01	.24	.34E-02	.23E-02	.25E-02	.24E-02	2.0	13.	16.	16.	.84	-17.84
SW03MAR25	1.1	3.9	.22E-02	.75	4.0	.12	1.9	.52E-01	.24	.41E-02	.25E-02	.25E-02	.24E-02	1.1	13.	14.	14.	.92	-8.42
SW03MAR29	.90	3.0	.19E-02	.54	3.6	.11	1.6	.46E-01	.23	.41E-02	.23E-02	.25E-02	.28E-02	1.0	11.	14.	14.	.81	-21.18
SW03 03/04AM	.91	3.1	.19E-02	3.9	.00	.10	1.5	.39E-01	.17	.34E-02	.18E-02	.50E-02	.76E-03	.63	10.	11.	11.	.97	-2.69
SW03 22/04AM	.29	1.6	.63E-03	1.0	.72E-01	.51E-01	.30	.98E-02	.43E-01	.85E-03	.75E-03	.21E-02	.76E-03	.18	3.6	3.6	3.6	1.0	.57
SW03 24/04AM	.54E-01	.27	.38E-03	.34E-01	.00	.26E-01	.72E-01	.22E-02	.43E-01	.85E-03	.32E-03	.19E-02	.76E-03	.40E-02	.51	.45	.45	1.1	11.91
SW03 26/04AM	1.3	5.3	.23E-02	.16	6.4	.15	2.3	.72E-01	.26	.44E-02	.40E-02	.38E-02	.34E-02	.50E-01	16.	.66	.66	24.	104.27
SW03 29/04AM	.13	.77	.35E-03	.21	.24	.26E-01	.19	.51E-02	.43E-01	.85E-03	.41E-03	.16E-02	.76E-03	.46	2.1	1.8	1.8	1.2	16.67
MAY02SW03AM	.17	1.0	.13E-03	.39	.14	.51E-01	.25	.66E-02	.22E-01	.85E-03	.37E-03	.86E-03	.76E-03	.63	2.7	2.4	2.4	1.1	10.15
MAY06SW03AM	.20	1.1	.50E-03	.29	.24	.26E-01	.29	.80E-02	.43E-01	.85E-03	.55E-03	.43E-03	.76E-03	.18	2.4	2.8	2.8	.86	-14.52
MAY09SW03AM	.25	1.4	.50E-03	.18	.51	.51E-01	.37	.10E-01	.87E-01	.85E-03	.62E-03	.14E-02	.76E-03	.45	3.3	3.6	3.6	.91	-8.90
MAY13SW03AM	.33	1.6	.72E-03	.18	.66	.51E-01	.50	.14E-01	.87E-01	.85E-03	.70E-03	.34E-02	.76E-03	.45	3.9	4.2	4.2	.94	-6.45
MAY22SW03AM	.47	2.0	.94E-03	1.0	.00	.51E-01	.71	.20E-01	.87E-01	.20E-02	.10E-02	.29E-02	.76E-03	.56	4.9	5.5	5.5	.89	-11.66
SW03JUN10-19	.75	2.9	.12E-02	1.7	.00	.10	1.2	.33E-01	.13	.27E-02	.14E-02	.45E-02	.76E-03	1.0	7.8	8.5	8.5	.92	-7.88
SW03 JUN27-05	1.1	2.7	.13E-02	.25	.85	.10	1.1	.32E-01	.13	.27E-02	.16E-02	.34E-02	.21E-02	1.1	7.4	7.6	7.6	.97	-3.00
SW-03-JUL.11	1.0	2.5	.12E-02	.57	.21	.77E-01	.98	.30E-01	.13	.34E-02	.16E-02	.24E-02	.34E-02	1.3	6.8	6.7	6.7	1.0	1.41
SW-03-JUL.25	.85	2.3	.11E-02	.39	.47	.10	.97	.30E-01	.13	.27E-02	.16E-02	.31E-02	.18E-02	.89	6.2	6.6	6.6	.94	-6.17
SW-03-JUL.31	.85	2.3	.91E-03	.36	.51	.77E-01	.99	.30E-01	.13	.27E-02	.16E-02	.21E-02	.18E-02	1.0	6.3	6.7	6.7	.93	-6.97

Table 5.14 Summary of Linear Regression for Iron Sulphate Interrelationships for Porewater (a)

```
JUNE READINGS
Regression of EC@25OC vs Acidity
             Regression Output:
Constant                              3268.8616
Std Err of Y Est                      2873.0071
R Squared                             0.3831928
No. of Observations                          31
Degrees of Freedom                           29

X Coefficient(s)      0.7190047
Std Err of Coef.      0.1693942
```

```
Regression of Fe2+ vs Fe
             Regression Output:
Constant                              -17.62986
Std Err of Y Est                      104.39566
R Squared                             0.9966967
No. of Observations                          31
Degrees of Freedom                           29

X Coefficient(s)      0.9354931
Std Err of Coef.      0.0100763
```

```
Regression of sulphate vs acidity
        Regression Output:
Constant                      0.014342
Std Err of Y Est              0.011876
R Squared                     0.870639
No. of Observations                 31
Degrees of Freedom                  29

X Coefficient(s)  0.499153
Std Err of Coef.  0.035012
```

```
Regression of Y vs X
             Regression Output:
Constant                              -0.000388
Std Err of Y Est                      0.0164216
R Squared                             0.9471197
No. of Observations                          31
Degrees of Freedom                           29

X Coefficient(s)      1.1033248
Std Err of Coef.      0.0484114
```

TABLE 5.14 Summary of Linear Regression for Iron Sulphate Interrelationships for Porewater (b)

```
AUGUST READINGS

Regression of EC@25OC vs Acidity
         Regression Output:
Constant                            4610.267
Std Err of Y Est                    2482.667
R Squared                           0.410953
No. of Observations                       16
Degrees of Freedom                        14

X Coefficient(s)  0.820265
Std Err of Coef.  0.262463


Regression of Fe2+ vs Fe
         Regression Output:
Constant                            -12.4519
Std Err of Y Est                    78.38874
R Squared                           0.996410
No. of Observations                       16
Degrees of Freedom                        14

X Coefficient(s)  0.279274
Std Err of Coef.  0.004479


Regression of sulphate vs. acidity
         Regression Output:
Constant                       0.023372
Std Err of Y Est               0.006698
R Squared                      0.901482
No. of Observations                  16
Degrees of Freedom                   14

X Coefficient(s)  0.400764
Std Err of Coef.  0.035408


Regression of Y vs X
         Regression Output:
Constant                            -0.01815
Std Err of Y Est                    0.071825
R Squared                           0.899565
No. of Observations                       16
Degrees of Freedom                        14

X Coefficient(s)  4.251491
Std Err of Coef.  0.379665
```

bottle), a wider difference in the cation-anion balance is expected, perhaps of the order of 10-20%.

Analysis of the June porewater data (Table 5.12a) and surface water data (Table 5.13) indicates that the cation-anion balance generally closes to within 20%. An exception are the last five samples listed on Table 5.12a (GW-06/B through GW-08/A) which are either excessive in cations or deficient in anions. The August porewater data show a systematic excess of cationic charge compared to anionic charge when total iron is taken to be Fe^{2+} and measured Fe(II) is taken to represent total iron. This assumption was initially made because measured values for Fe(II) are consistently in excess of measured total iron (Fe by ICP). A plot of measured Fe^{2+} versus total iron for August (Figure 5.7d) shows that there is a good correlation between measured Fe^{2+} and total iron, but that Fe^{2+} is consistently four times the measured Fe (total) value. It is suspected that a systematic error (e.g., calibration of Fe(II) standards or some other reason) must be present in the measured field values for Fe(II) in porewater during the August campaign. A rigorous inspection was made of field notes etc., to ascertain the probable error, but the search was unsuccessful.

Assuming that measured Fe (total) represents Fe(II) and that there is no Fe(III) present in the porewater samples, the cation-anion balance was recalculated (see Table 5.11c). The balance generally closes to within ± 10%.

With respect to surface water samples, it is doubtful that the same bias of measured values for Fe(II) are found in the surface water samples because a different field technician made the measurements at different times and because a four times difference is not evident in the data.

Plots of conductivity versus acidity, sulphate versus acidity (in units of equivalence), Fe^{2+} versus Fe and Y versus X are given in Figures 5.3 to 5.6 for tailings porewater samples. Y is the charge balance from a few cations. It is calculated using Fe^{2+}, Fe^{3+}, pH and Al (assumed as a 2.5 plus charge). X (the abscissa) is the acidity divided by 50,000. The plot of Y versus X thus represents a comparison of calculated acidity to measured acidity. These plots give the potential user of this data some evidence for the self-consistency of measurement of these different parameters.

Plots of duplicate values are given in Figure 5.7 for tailings porewater samples. There are six sets of duplicates available from the June and August sampling campaigns. The data are given the following plots:

(a) aluminum
(b) calcium
(c) chromium
(d) iron
(e) potassium
(f) magnesium
(g) manganese
(h) sodium
(i) nickel
(j) lead
(k) silica
(l) strontium
(m) titanium
(n) zinc
(o) fluoride
(p) chloride
(q) sulphate
(r) ammonia
(s) uranium
(t) radium-226
(u) thorium-230

The prime laboratory for non-radionuclide parameters was Barringer while the check laboratory was BEAK. For radionuclide parameters, Chemex was the prime laboratory and Monenco was the check laboratory.

There is reasonable agreement for all parameters except chromium, lead, titanium, zinc, fluoride, and ammonia among the non-radionuclide parameters. The lack of agreement for lead is due to apparent detection limit problems of Barringer (see next section). There is agreement for uranium and Th-230, but more scatter for Ra-226.

Regression plots of various thorium parameters might allow some determination of laboratory measurement ability and of geochemical mechanisms involved in controlling thorium geochemistry. A reasonable assumption with respect to Th geochemistry is that Th-230 is coprecipitated with thorium hydroxide formed in the leaching tank. Hence, Th-230 in porewater is derived from dissolution of $Th(OH)_4(s)$ while Th-232 and Th-228 would be derived from dissolution of $Th(OH)_4(s)$ and other thorium containing minerals (e.g., monazite). The relationship of Th-230 to total thorium (Th-232) in the porewater might be used to assess the relative influence of $Th(OH)_4(s)$ and other minerals upon the origins of Th-232 in the porewater.

A few points concerning the graphs are as follows:

1. There is scatter in the relationship between Th-230 and Th-232 but less scatter in the relationship of Th-230 to total thorium (measured by ICP). This results from the scatter in the Th-232: total thorium relationship. The chemical analyses was made upon sequential samples, rather than the same sample. Hence one cannot, necessarily, expect an exact relationship between Th-232 and thorium.

2. With the exception of two or three points, Th-228 is exactly correlated with Th-232. Inspection of the original data shows that the Th-228 values are generally the same as Th-232. This is unexpected because even analytical variability for duplicate samples would not always be the same. This is discussed further in Appendix 1.

5.8.3 Results of QA Audit

Samples of a known composition were submitted to Monenco, Chemex and SRC for radionuclide analysis, and to Barringer, BEAK and SRC for non-radionuclide analysis. Analytical results for radionuclides are given in Table 5.15a and for non-radionuclides in Table 5.15b. The "known" concentrations of the samples are given in Table 5.15c(i). An estimate of the levels of other parameters is given in Table 5.15c(ii). The chemicals used to prepare the stock solutions are given in Table 5.15d.

The master samples for radionuclide analysis were numbers 7, 9 and 10. The iron (II) sulphate and calcium sulphate matrix was made up to emulate the porewater composition of the Lacnor tailings management area. Samples 1 to 3 were formed by dilution of samples 7, 9, and 10 by two-, eight- and ten-fold, respectively. These samples were formed to emulate surface waters and were analyzed only for non-radionuclide parameters. The following are duplicates: sample 1 and 4, samples 2 and 6, samples 3 and 5, and samples 7 and 8.

The synthetic samples 7, 9, and 10 for radionuclide analysis were prepared by CANMET Laboratories and submitted directly by CANMET under a covering letter from the project team. The synthetic samples 1-6 were also diluted by CANMET and submitted for analysis. The Fe, Ca, K, SO_4 contents of the synthetic samples 7-10 for non-radionuclide analyses were prepared by CANMET. The contents for Al, Ba, Cd, Co, Cr, Pb were prepared by BEAK and added into the samples prepared by CANMET, and then submitted to the Laboratories.

The results of the radionuclides analyses indicate that the ratio of the measured values to known values ranges with 0.8 to 1.2 (the expected ratio is 1.0) for all samples and laboratories except for the thorium-230 analyses by Chemex for the sample having the lowest thorium-230 content. The cause of this is not understood at this time.

The results for the non-radionuclide parameters given in Table 5.15(b) show general agreement with the known values. It is left to the readers to make an assessment of the degree of agreement which is desired for their particular purpose. A few points are in order for the trace constituents.

(i) For many of the trace constituents, a small concentration is measured by all laboratories. It is difficult to assess what should be a proper "zero" concentration because the trace metal level in the distilled water used to prepare the samples is not known.

(ii) The laboratories show general agreement with known values for the addition of trace metals. This data can then be used to assess the capability of DCP and ICP to measure concentrations of Al, Ba, etc., in the 0.1 to 1.0 mg/L range on the presence of a calcium-iron matrix. There is one exception: the Barringer analysis for Pb is low, suggesting that their correction for a calcium interference for Pb is excessive.

TABLE 5.15 RESULTS OF QUALITY ASSURANCE AUDIT WITH SYNTHETIC POREWATER SAMPLES

TABLE 5.15 (a)(i) VALUES OF RADIONUCLIDE PARAMETERS MEASURED BY LABORATORIES

Parameter	Sample No.	Known Value	Monenco		SRC		Chemex	
Ra-226	1	2.8	2.51	2.94	2.9	2.8	2.3	2.4
	2	10.6	9.0	9.0	10	11	8.7	9.3
	3	1.17	1.18	1.08	1.3	1.2	0.97	0.93
Th-230	1	0.58	0.47	0.47	0.6	0.55	2.2	1.9
	2	5.82	4.6	4.1	8	6	7.7	7.2
	3	0.80	0.62	0.42	0.7	0.8	1.1	1.0

TABLE 5.15.(a)(ii) RATIO OF MEASURED VALUE TO KNOWN VALUE

Parameter	Sample No.	Known Value	Monenco		SRC		Chemex	
Ra-226	1	1.	0.90	1.05	1.04	1.0	0.82	0.86
	2	1.	0.85	0.85	.94	1.04	0.82	0.88
	3	1.	1.01	0.92	1.11	1.03	0.83	0.79
Th-230	1	1.	0.81	0.81	1.03	0.95	3.8	3.3
	2	1.	0.79	0.70	1.37	1.0	1.3	1.24
	3	1.	0.78	0.50	0.88	1.0	1.38	1.25

TABLE 5.15(b)(i)

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Parameter	Sample 1	Sample 4 (Dupl. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7++	Sample 8++ (Dupl. of Sample 7) *	Sample 9++	Sample 10++
Ag (mg/L)	L .005	L .005	L .005	L .005	L .005	L .005	L .005	L .005	L .005	L .005
Al (mg/L)	L .01	L .01	.05	L .01	L .01	L .01	$2.56^{(2)}$	$.65^{(.2)}$	$2.44^{(2.)}$	$2.22^{(2.)}$
B (mg/L)	L .004	.016	L .004	0.56	.043	.039	.607	.650	1.12	2.26
Ba (mg/L)	L .005	L .005	L .005	L .005	L .005	L .005	$.184^{(.2)}$	$.018^{(.02)}$	$.173^{(.2)}$	$.166^{(.2)}$
Be (mg/L)	L .0005	L .0005	L .0005	L .0005	L .0005	L .0005	.0005	L .0005	.0021	.0016
Ca (mg/L)	175	177	63.4	60.1	42.7	44.2	331	344	459	426
Cd (mg/L)	L .01	L .01	L .01	L .01	L .01	L .01	$.92^{(1.)}$	$.10^{(.1)}$	$.96^{(1.)}$	$.92^{(1.)}$
Co (mg/L)	L .05	L .05	L .05	L .05	L .05	L .05	$.80^{(1.)}$	L $.05^{(.1)}$	$.85^{(1.)}$	$.59^{(1.)}$
Cr (mg/L)	.03	.03	.03	.03	.02	.02	$.85^{(1.)}$	L $.01^{(.1)}$	$.68^{(1.)}$	$.47^{(1.)}$
Cu (mg/L)	.017	.013	.012	.009	.008	.012	.040	.043	.104	.163
Fe (mg/L)	410	415	242	235	349	352	779	808	1820	3390
K (mg/L)	12	12	7	6	8	9	26	26	54	95
Mg (mg/L)	55.4	56.5	22.6	21.4	6.05	6.22	103	106	165	60.1
Mn (mg/L)	.52	.52	.34	.32	.47	.47	1.03	1.06	2.45	4.60
MO (mg/L)	.2	.3	L .2	L .2	L .2	L .2	$1.5^{(1.)}$	$1.0^{(.1)}$	$2.4^{(1.)}$	$6.2^{(1.)}$
Na (mg/L)	L 1	L 1	L 1	L 1	L 1	L 1	L 1	L 1	2	2
Ni (mg/L)	.06	.07	L .05	L .05	L .05	L .05	.11	.11	.20	.30
P (mg/L)	L .5	L .5	L .5	L .5	L .5	L .5	L .5	L .5	L .5	L .5
Pb (mg/L)	L .05	L .05	L .05	L .05	L .05	L .05	L $.05^{(1.)}$	L $.05^{(.1)}$	L $.05^{(1.)}$	L $.05^{(1.)}$
Si (mg/L)	.18	.18	.18	.18	.06	.06	.17	.19	.53	.24
Sr (mg/L)	.051	.050	.017	.016	.010	.011	.094	.095	.124	.116
Th (mg/L)	L .05	L .05	L .05	L .05	L .05	L .05	L .05	L .05	.42	.62
Ti (mg/L)	L .005	L .005	L .005	L .005	L .005	L .005	L .005	L .005	.040	.034
V (mg/L)	L .005	L .005	.010	L .005	L .005	L .005	L .005	.010	.056	.062
Zn (mg/L)	L .05	L .05	L .05	L .05	L .05	L .05	L .05	L .05	.06	.11
Zr (mg/L)	L .05	L .05	L .05	L .05	L .05	L .05	L .05	L .05	L .05	L .05
AN/CAT %	13.1	15.7	10.7	15.6	10.9	13.7				

TABLE 5.15(b)(i)

MEASUREMENT OF KNOWNS BY BARRINGER MAGENTA

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Parameter	Sample 1	Sample 4 (Dupl. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7++	Sample 8++ (Dupl. of Sample 7) *	Sample 9++	Sample 10++
PH	1.90	1.89	2.31	2.30	1.91	1.90				
F- (mg/L)	.68	.68	.27	.27	.27	.27				
CL- (mg/L)	450	496	230	245	659	751				
NO2- (mg/L)	L .2	L .2	L .2	L .2	L .2	L .2				
PO4-3 (mg/L)	L .1	L .1	L .1	L .1	L .1	L .1				
BR- (mg/L)	L .5	L .5	L .5	L .5	L .5	L .5				
NO3- (mg/L)	L .5	L .5	L .5	L .5	L .5	L .5				
SO4= (mg/L)	2600	2730	884	959	996	1030				

Instrumentation: ICP: Ag to Zr; Ion Chromatography - F to SO_4^{2-}.

* Duplicate of Sample 7, except for Al, Ba, Cd, Co, Cr, Mo, Pb which were added in the amount indicated in brackets.

++ Al, Ba, Cd, Co, Cr, Mo, Pb added in amounts indicated in brackets.

TABLE 5.15(b)(ii)

MEASUREMENT OF KNOWNS BY BEAK ANALYTICAL SERVICES

Parameter	Sample 1	Sample 4 (Dupl. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7++	Sample 8++ (Dupl. of Sample 7) *	Sample 9++	Sample 10++
IC Scan: mg/L										
Fluoride	0.2/0.4	0.9	0.05	0.05	0.05	0.05				
Chloride	400	370	210	210	620/670	640				
Nitrite-N	L 3	L 3	L 1	L 3	L 3	L 3				
Ortho-Phosphate-P	L 0.5	L 0.5	L 0.5	L 0.5	L 0.5	L 0.5				
Nitrate-N	L 0.3	L 0.3	L 0.3	L 0.3	L 0.3	L 0.3				
Sulphate	2200	1920	760	760	800/760	750				
DCP Scan: mg/L										
Beryllium	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	0.010
Molybdenum	0.07	0.05	0.03	0.02	0.03	0.02	$1.01^{(1)}$	$0.21^{(.1)}$	$1.41^{(1)}$	$1.56^{(1)}$
Calcium	179	167	98	81	58	44	460	400	570	370
Vanadium	0.015	0.015	0.010	L 0.005	0.005	L 0.005	0.030	0.035	0.075	0.095
Aluminum	0.18	0.12	0.07	0.06	0.05	0.04	$1.88^{(2.0)}$	$0.46^{(.2)}$	$2.4^{(2)}$	$2.3^{(2)}$
Magnesium	67	55	27	25	7.8	6.5	107	121	220	76
Barium	0.02	L 0.01	L 0.01	L 0.01	L 0.01	L 0.01	$0.20^{(.2)}$	$0.04^{(.02)}$	$0.30^{(.2)}$	$0.29^{(.2)}$
Potassium	14.5	15.3	8.1	8.0	13.2	11.7	29	30	57	89
Strontium	0.09	0.05	0.03	0.02	0.02	.01	0.11	0.13	0.21	0.20
Sodium	2.4	2.2	1.4	0.8	L 0.2	L 0.2	3.8	5.6	9.4	10.4
Zinc	0.040	0.040	0.010/0.005	0.020	0.030	0.030	0.06	0.06	0.130	0.125
Cadmium	0.125	0.135	0.055/0.070	0.080	0.110	0.115	$1.23^{(1)}$	$0.38^{(.1)}$	$1.63^{(1)}$	$1.96^{(1)}$
Manganese	0.52	0.50	0.29/0.30	0.29	0.43	0.43	1.03	1.05	2.5	4.3
Cobalt	0.04	0.05	0.02/0.02	0.030	0.03	0.05	$1.12^{(1)}$	$0.20^{(.1)}$	$1.22^{(1)}$	$1.16^{(1)}$
Copper	0.015	0.015	0.010/0.010	0.015	0.015	0.010	0.035	0.030	0.060	0.080
Silver	0.04	L 0.01	L 0.01/L 0.01	0.02	L 0.01	0.06	0.03	0.05	0.08	0.09
Iron	340	360	220	161	310	300/320	730	720	1570	3000
Lead	0.27	0.29	0.13/.12	0.17	0.13	0.31	$1.47^{(1)}$	$0.61^{(.1)}$	$2.1^{(1)}$	$2.0^{(1)}$

TABLE 5.15 (b)(ii)

MEASUREMENT OF KNOWNS BY BEAK ANALYTICAL SERVICES

Page 2 of 2

Parameter	Sample 1	Sample 4 (Dup. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7	Sample 8 (Dupl. of Sample 7) *	Sample 9++	Sample 10++
Chromium	0.030	0.030	0.015/0.010	0.020	0.010	0.040	$1.08^{(1)}$	$0.15^{(.1)}$	$1.10^{(1)}$	$1.03^{(1)}$
Nickel	0.06	0.06	0.04/0.04	0.04	0.04	0.07	0.12	0.13	0.29	0.42
Silica (SiO_2)	0.17	0.21	0.14	0.08	0.15	0.03	0.69	0.50	0.94	0.19
Titanium	0.14	0.14	0.06	0.05	0.05	0.05				

Measurement Instrumentation: Ion Chromatography: F, Cl, NO_2^-, NO_3^-, PO4, SO_4^{2-}; others by DCP Scan.

* Duplicate of Sample 7, except for Al, Ba, Cd, Co, Cr, Mo, Pb which were added in the amount indicated in brackets.

++ Al, Ba, Cd, Co, Cr, Mo, Pb added in amounts indicated in brackets.

TABLE 5.15(b)(iii)

MEASUREMENT OF KNOWNS BY SASKATCHEWAN RESEARCH COUNCIL

Parameter	Sample 1	Sample 4 (Dupl. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7++	Sample 8++ (Dupl. of Sample 7) *	Sample 9 ++	Sample 10++
Cl (mg/L)	410	420	190	200	670	670				
SO4 (mg/L)	1900	1900	700	700	760	780				
NO2 (mg/L)	Not Req	Not Req	Not Req	Not Req	Not Req	Not Req				
NO3 (mg/L)	Not Req	Not Req	Not Req	Not Req	Not Req	Not Req				
PO4 (mg/L)	Not Req	Not Req	Not Req	Not Req	Not Req	Not Req				
B (mg/L)	L 0.05*	L 0.05*	L 0.05*	L 0.05	L 0.05*	L 0.05	(L 0.05*)	(L 0.05*)	(L 0.05*)	(L 0.05*)
Br (mg/L)	Not Req	Not Req	Not Req	Not Req	Not Req	Not Req				
F (mg/L)	L 0.01	L 0.01	0.06	0.06	L 0.01	0.06				
P (mg/L)	(0.66*)	(0.75*)	(0.38*)	(0.36*)	(0.47*)	(0.52*)	(1.6*)	(1.5*)	(3.0*)	(4.7*)
Ag (mg/L)	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.005	L 0.005	L 0.005	L 0.005
Al (mg/L)	0.063	0.055	0.048	0.036	0.029	0.038	2.1 $^{(2.)}$	0.42 $^{(.2)}$	2.1 $^{(2.)}$	1.9 $^{(2.)}$
Ba (mg/L)	0.008	0.008	0.006	0.007	0.006	0.006	0.17 $^{(.2)}$	0.014 $^{(.02)}$	0.16 $^{(.2)}$	0.16 $^{(2.)}$
Be (mg/L)	0.058	0.059	0.038	0.036	0.055	0.055	0.10	0.10	0.23	0.42
Ca (mg/L)	210	200	69	69	51	52	350	360	480	440
Cd (mg/L)	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	1.0 $^{(1.)}$	0.096 $^{(.1)}$	1.0 $^{(1.)}$	1.0 $^{(1.)}$
Co (mg/L)	0.013	0.013	0.009	0.008	0.012	0.013	0.91 $^{(1.)}$	0.12 $^{(.1)}$	0.93 $^{(1.)}$	0.97 $^{(1.)}$
Cr (mg/L)	0.023	0.023	0.016	0.016	0.024	0.026	0.94 $^{(1.)}$	0.14 $^{(.1)}$	0.96 $^{(1.)}$	1.1 $^{(1.)}$
Cu (mg/L)	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.001	L 0.005	L 0.005	L 0.005	L 0.005
Fe (mg/L)	350	340	210	180	280	310	800	820	1900	3400
K (mg/L)	16	16	8.8	8.9	12	12	29	29	54	94
Mg (mg/L)	58	55	24	24	6.8	6.7	94	95	160	50
Mn (mg/L)	0.36	0.38	0.24	0.24	0.36	0.37	0.81	0.83	1.9	3.5
Mo (mg/L)	0.041	0.042	0.026	0.024	0.034	0.036	0.86 $^{(1.)}$	0.084 $^{(.1)}$	0.84 $^{(1.)}$	0.82 $^{(1.)}$
Na (mg/L)	0.2	0.2	0.2	L 0.2	L 0.2	L 0.2	0.35	0.41	0.66	0.27
Ni (mg/L)	0.029	0.035	0.020	0.023	0.029	0.032	0.078	0.066	0.17	0.34
Pb (mg/L)	0.11	0.10	0.084	0.069	0.090	0.090	1.1 $^{(1.)}$	0.27 $^{(.1)}$	1.4 $^{(1.)}$	1.8 $^{(1.)}$
Si (mg/L)	L 0.05	L 0.05	L 0.05	L 0.05	0.08	0.12	L 0.2	L 0.2	L 0.2	L 0.2

TABLE 5.15 (b)(iii)

MEASUREMENT OF KNOWNS BY SASKATCHEWAN RESEARCH COUNCIL

Page 2 of 2

Parameter	Sample 1	Sample 4 (Dupl. of Sample 1)	Sample 2	Sample 6 (Dupl. of Sample 2)	Sample 3	Sample 5 (Dupl. of Sample 3)	Sample 7++	Sample 8++ (Dupl. of Sample 7) *	Sample 9 ++	Sample 10++
Ti (mg/L)	L 0.001	L 0.001	0.002	0.002	L 0.001	L 0.001	L 0.005	L 0.005	L 0.005	L 0.005
V (mg/L)	0.08	0.09	0.05	0.05	0.07	0.07	0.18	0.19	0.39	0.64
W (mg/L)	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.005	L 0.02	L 0.02	L 0.02	L 0.02
Zn (mg/L)	0.086	0.065	0.057	0.067	0.066	0.076	0.092	0.092	0.23	0.44

Not Req - SRC terminology which means "levels are too low to detect by ion chromatography".

Measurement Instrumentation: Cl - $AgNO_3$ titr.; SO_4: gravi; NO_2, NO3; PO4; Br- ion chromatography; F: fluoride electrode; others: ICP-AES.

* Parameters measured by ICP.

+ Duplicate of Sample 7, except for Al, Ba, Ca, Co, Cr, Mo, Pb which were added in the amount indicated in brackets.

++ Al, Ba, Ca, Co, Cr, Mo, Pb added in amounts indicated in brackets.

		Concentration of Constituent (mg/L)			
Sample	Constituent	Known Value	Beak Measurement	Barringer Measurement	SRC Measurement
1, 4	Fe	400	340, 360	410, 415	350, 340
	Ca	180	179, 167	175, 177	210, 200
	Mg	63	67, 55	55, 57	67, 55
	K	15	15, 15	12, 12	16, 16
	SO_4^{2-}	1600	2200, 1920	2600, 2730	1900, 1900
2, 6	Fe	225	220, 161	242, 235	210, 180
	Ca	60	98, 81	63.4, 60.1	69, 69
	Mg	25	27, 25	22.6, 21.4	24, 24
	K	7.5	8.1, 8	7, 6	8.8, 8.9
	SO_4^{2-}	683	760, 760	884, 959	700, 700
3, 5	Fe	340	310, 300/320	349, 352	280, 310
	Ca	45	58, 44	42.7, 44.2	51, 52
	Mg	7	7.8, 6.5	6.05, 6.22	6.8, 6.7
	K	11	13.2, 11.7	8, 9	12, 12
	SO_4	761	800, 750	996, 1030	760, 780
7, 8	Fe	800	730, 720	779, 808	800, 820
	Ca	360	460, 400	331, 334	350, 360
	Mg	125	107, 121	103, 106	94, 95
	K	30	29, 30	26, 26	29, 29
7	Al	2	1.88	2.56	2.1
	Ba	.2	0.20	.184	.17
	Cd	1	1.23	.92	1.0
	Co	1	1.12	.80	0.91
	Cr	1	1.08	.85	0.94
	Mo	1	1.01	1.5	0.86
	Pb	1	1.47	L .05	1.1
8	Al	.2	.46	.65	.42
	Ba	.02	.04	.018	.014
	Cd	.1	.38	.1	.096
	Co	.1	.20	.05	.12
	Cr	.1	.15	L .01	.14
	Mo	.1	.21	1.	.084
	Pb	.1	.61	L .05	.27
9	Fe	1800	1570	1820	1900
	Ca	480	570	459	480
	Mg	200	220	165	160
	K	60	57	54	54
	Al	2.	2.4	2.44	2.1
	Ba	.2	0.30	.173	.16
	Cd	1.	1.63	.96	1.
	Co	1.	1.22	.85	.93
	Cr	1.	1.1	.68	.96
	Mo	1.	1.41	2.4	.84
	Pb	1.	2.1	L .05	1.4
10	Fe	3400	3000	3390	3400
	Ca	450	370	426	440
	Mg	70	76	60.1	50
	K	110	89	95	94
	Al	2.	2.3	2.22	1.9
	Ba	.2	.29	.166	.16
	Cd	1.	1.96	.92	1.
	Co	1.	1.16	.59	.97
	Cr	1.	1.03	.47	1.1
	Mo	1.	1.56	6.2	.82
	Pb	1.	2.0	L .05	1.8

TABLE 5.15 (c)(i) VALUES OF PARAMETERS IN SYNTHETIC POREWATER AND SURFACE WATER SAMPLES

Constituent	Sample 7	Sample 9	Sample 10
pH	2.0	2.4	1.9
Fe (II) (mg/L)	800	1800	3400
Ca (mg/L)	360	480	450
Mg (mg/L)	125	200	70
K (mg/L)	30	60	110
SO_4^{2-} (mg/L)	3210	5470	7610
Ra-226 (Bq/L)	2.80	10.6	1.17
Th-230 (Bq/L)	0.58	5.82	0.80

Sample 1, 4 duplicate of Sample 7, but diluted 1:2.
Sample 2, 6 duplicate of Sample 9, but diluted 1:8.
Sample 3, 5 duplicate of Sample 10, but diluted 1:10.
Sample 8 duplicate of Sample 7.

Constituent	Sample 1/4	Sample 2/6	Sample 3/5
Fe(II)	400	225	340
Ca	180	60	45
Mg	63	25	7
K	15	7.5	11
SO_4^{2-}	1600	683	761

TABLE 5.15(c)(ii) ESTIMATE OF OTHER PARAMETERS IN SYNTHETIC WATER SAMPLES

Sample Number	Parameter Value (mg/L) Al	Ba	K	Mn	Na	Pb
Sample 7	.015	L .002	0.001	L .003	.009	.004
Sample 9	0.2	L .002	0.013	L .003	.12	.05
Sample 10	0.027	L .002	0.002	L .003	.02	.01

Note Values of other parameters cannot be calculated because contents are not given on chemical bottles.

TABLE 2.11(c)(iii) ESTIMATE OF OTHER PARAMETERS DUE TO Al, Ba, Cd, Co, Cr, Pb ADDITION IN SAMPLE NUMBERS 7, 9, 10

Ni from Cobalt Stock	0.005 mg/L
Zn from Cobalt Stock	0.001 mg/L
Pb from Cobalt Stock	L 0.001 mg/L
Na from Cr Stock	L 0.0005 mg/L
K from Cr Stock	1.5 mg/L

TABLE 5.15 (d) STOCK SOLUTIONS USED FOR PREPARATION OF SYNTHETIC WATER SAMPLES

(i) Major Elements

Element	Chemical
Fe (II)	$FeSO_4 \cdot 7H_2O$
Ca	$CaSO_4 \cdot 2H_2O$
Mg	$Mg\ SO_4$
K	K_2SO_4
SO_4^{2-}	H_2SO_4
Ra-226	NBS Certified Ra-226 Solution and CRM BL-5
Th-230	CRM BL-5

(ii) Minor Elements (for Samples 7, 8, 9, 10)

Element	Chemical
Al	Metal
Ba	$Ba\ (C10_4)_2\ 3H_2O$
Cd	Metal
Co	$CoCl_2$
Cr	K_2CrO_4
Pb	$PbNO_3$

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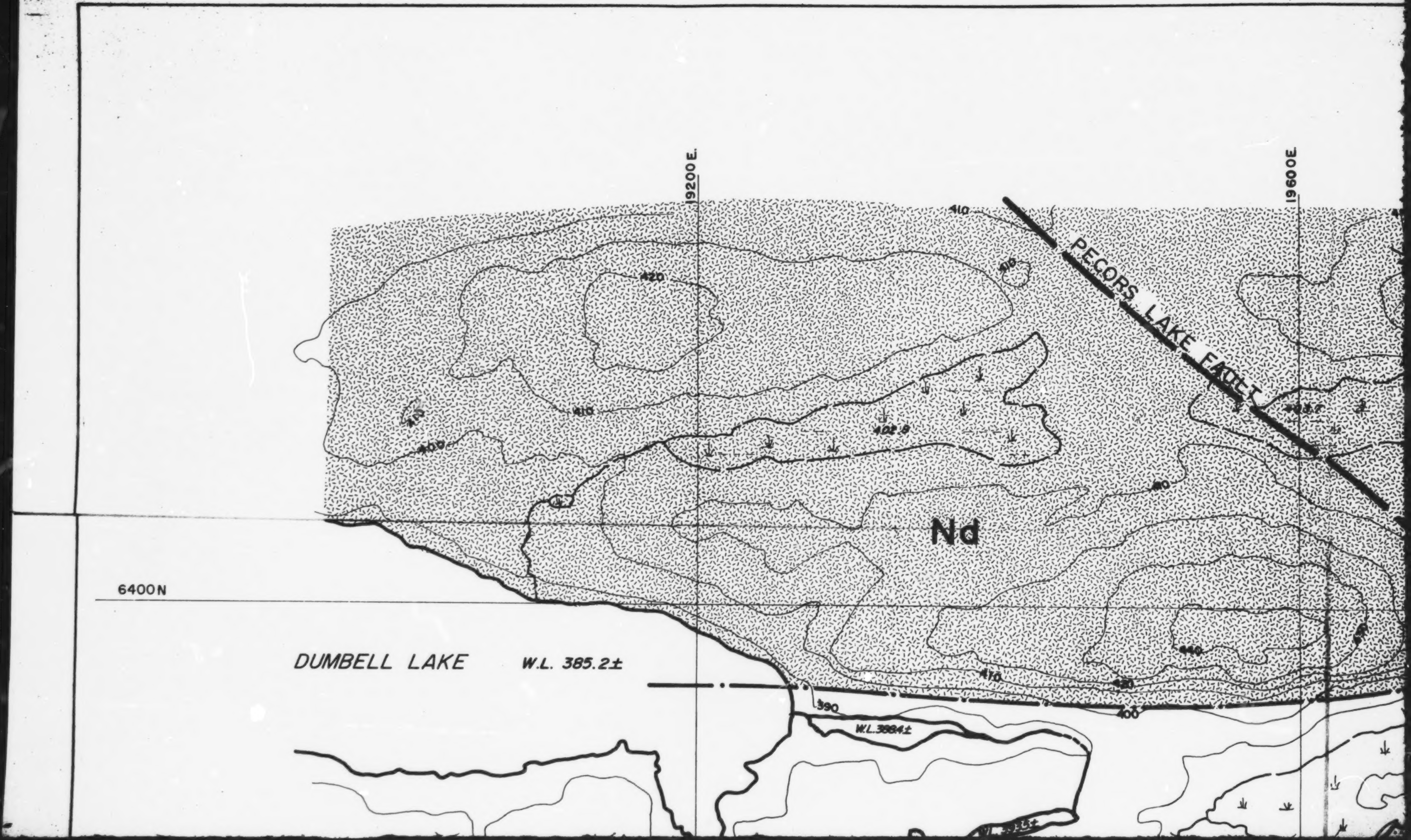
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PECORS LAKE FAULT
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410
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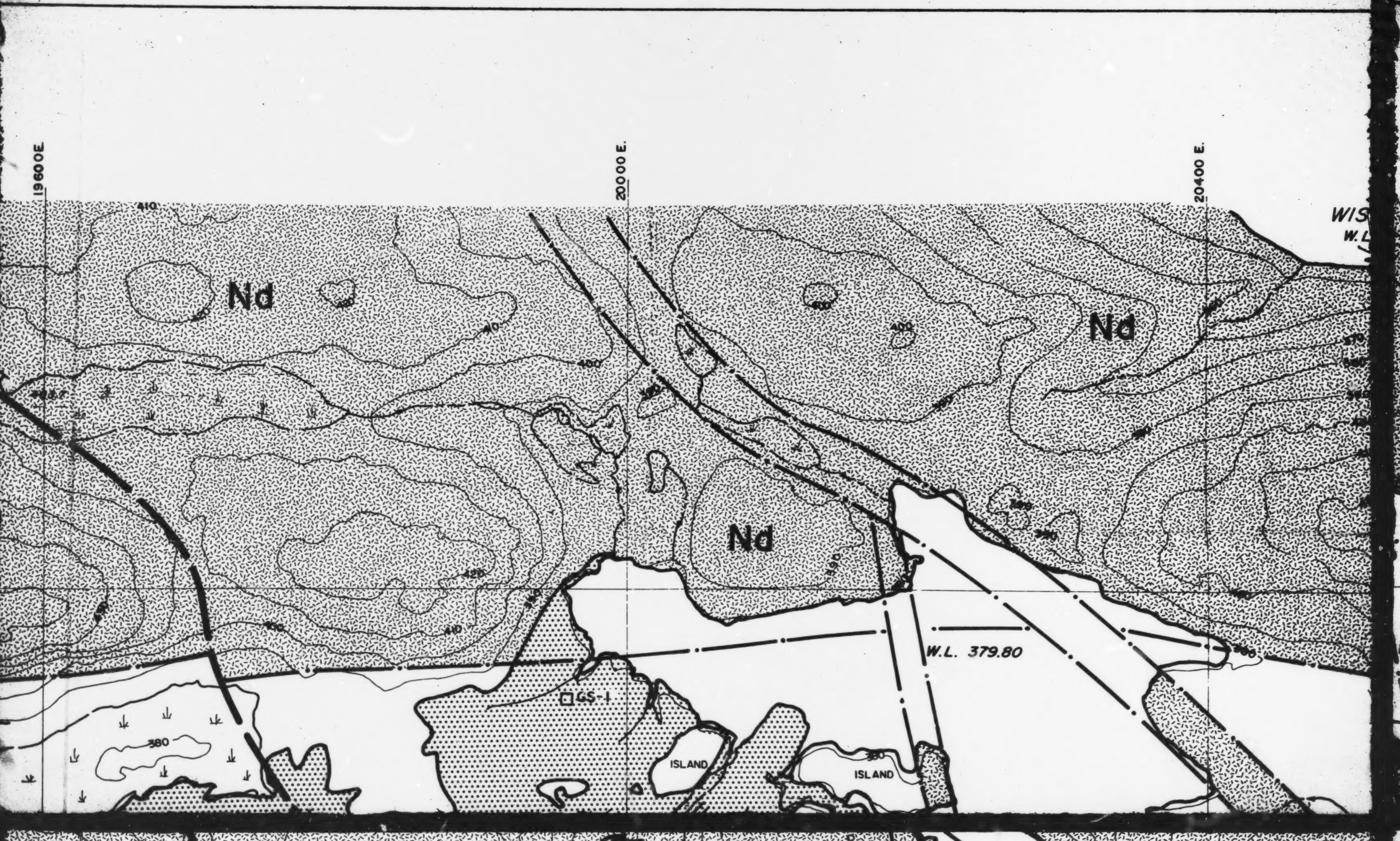
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Nd
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400
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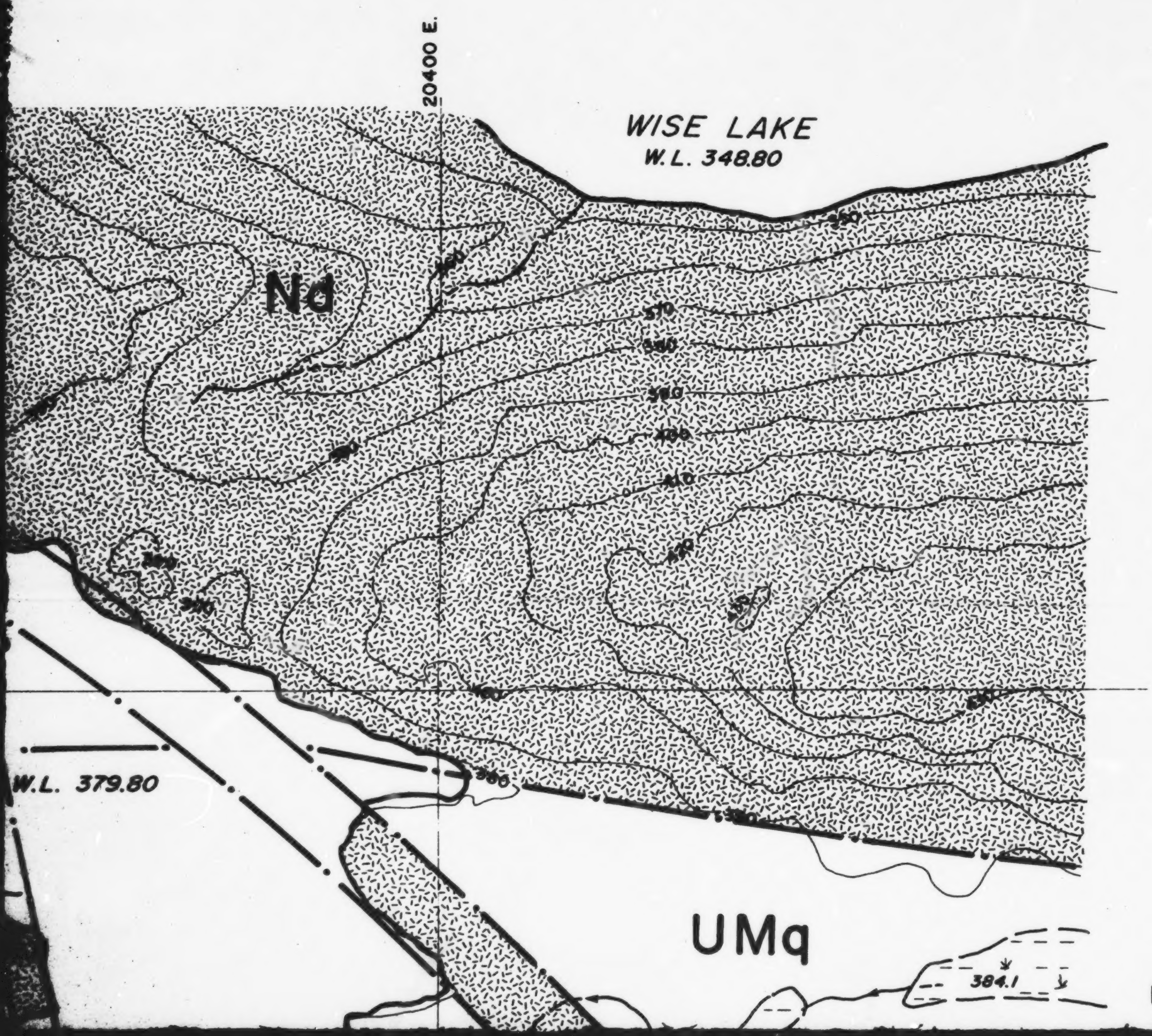
410
400
400
400
420
410
400
380
390
W.L. 379.80
GS-1
ISLAND
ISLAND
380

FIGURE 1.1

GEOHYDROLOGY AND GEOCHEMISTRY

LOCATION OF SAMPLING AND MONITORING STATIONS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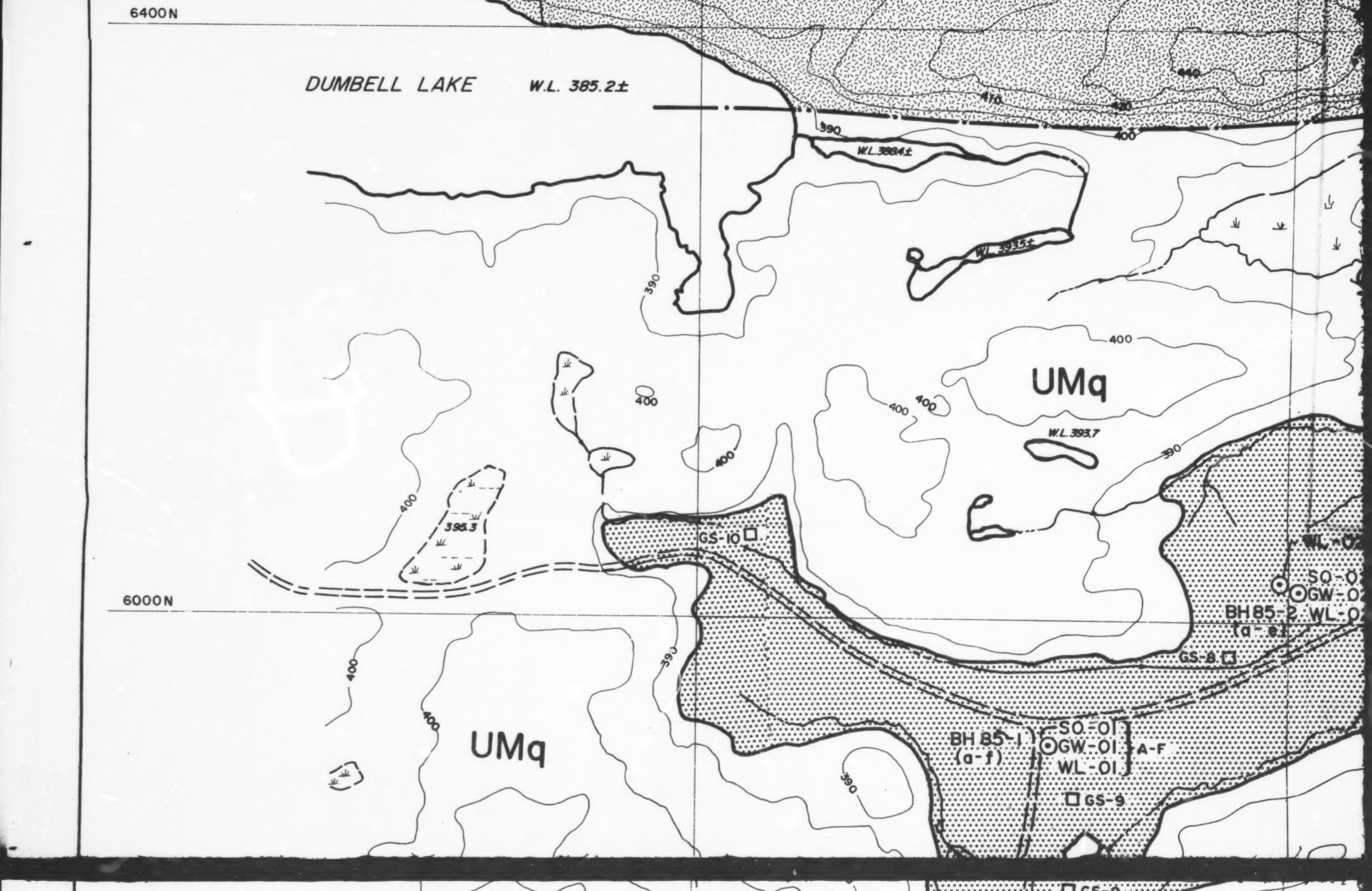
WISE LAKE
W.L. 348.80
Nd
370
380
390
400
410
420
W.L. 379.80
UMq
384.1

LEGEND :

▨ AREAS OF EXPOSED TAILINGS

□ GS-1 — SURFACE 'GRAB' SAMPLE

BH85-1 (a-f) — BOREHOLES; NUMBER, LOCATION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400
400
400
400
400
UMq
W.L. 393.7
390
395.3
GS-10
WL-02
SO-02
GW-02
BH 85-2
(a-e)
WL-02
6000N
390
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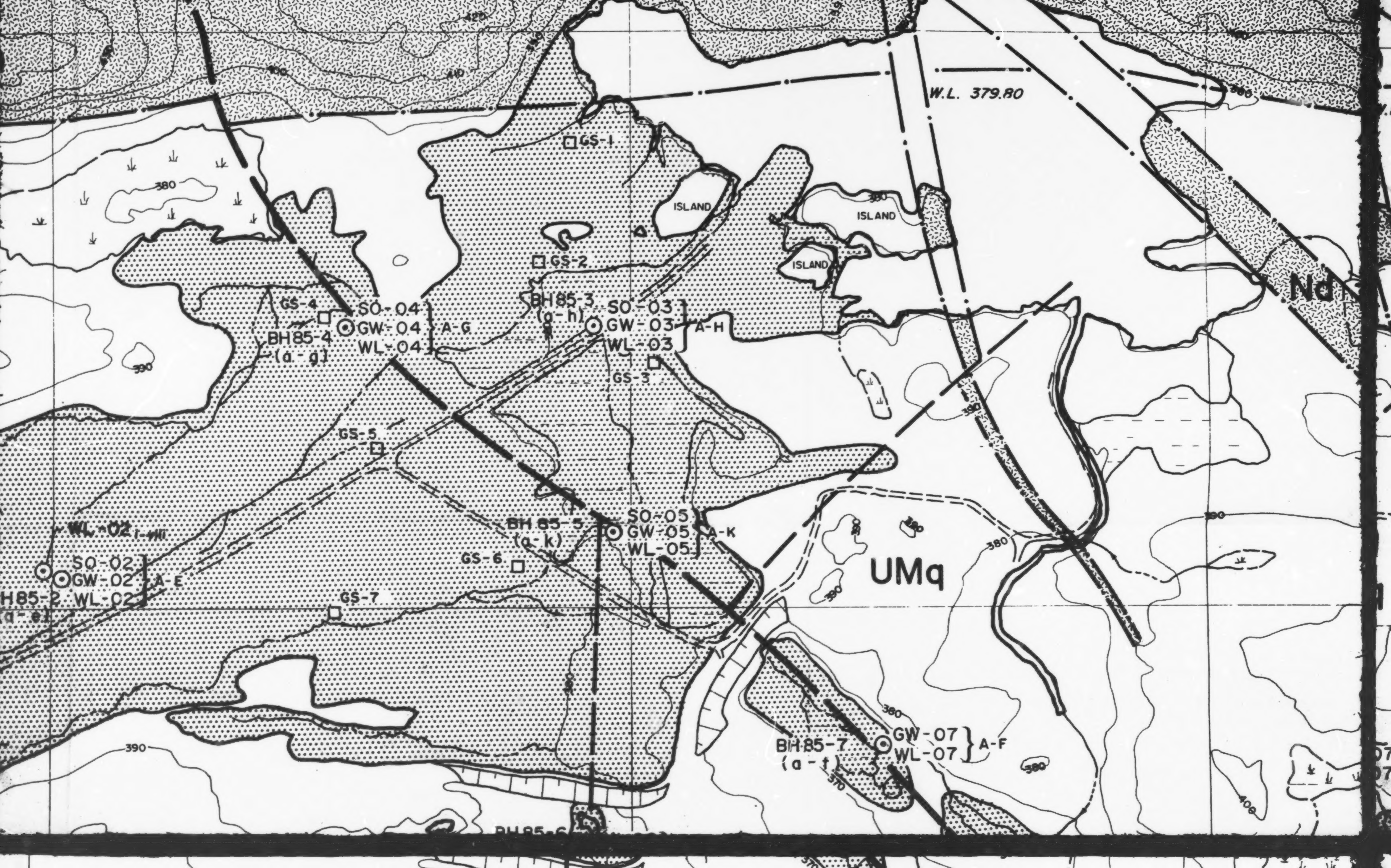
GS-9
GS-9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ISLAND
ISLAND
GS-2
GS-4
SO-04
GW-04
WL-04
A-G
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(a-g)
BH85-3
(a-h)
SO-03
GW-03
WL-03
A-H
GS-3
Nd
GS-5
BH85-5
(a-k)
SO-05
GW-05
WL-05
A-K
GS-6
UMq
WL-02
SO-02
GW-02
WL-02
A-E
BH85-2
(a-e)
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400
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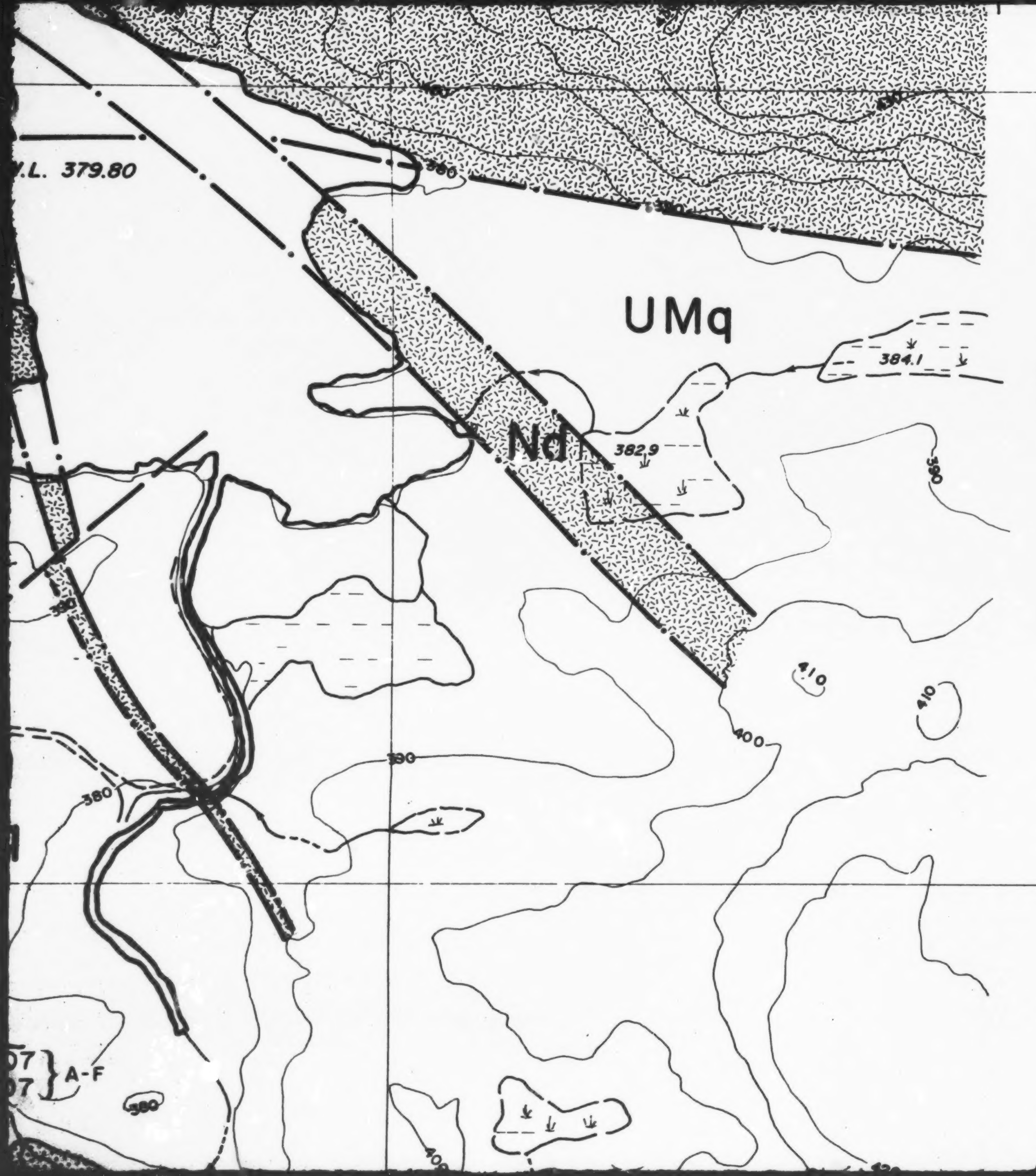


LEGEND :

▨	AREAS OF EXPOSED TAILINGS
□ GS-1	SURFACE 'GRAB' SAMPLE
BH85-1 (a - f)	BOREHOLES; NUMBER, LOCATION
⊙ SO-01 } A-F	TAILINGS SOLIDS SAMPLING STATION
GW-01 } A-F	GROUNDWATER SAMPLING STATION
WL-01	WATER LEVEL MONITORING STATION

GEOLOGY :

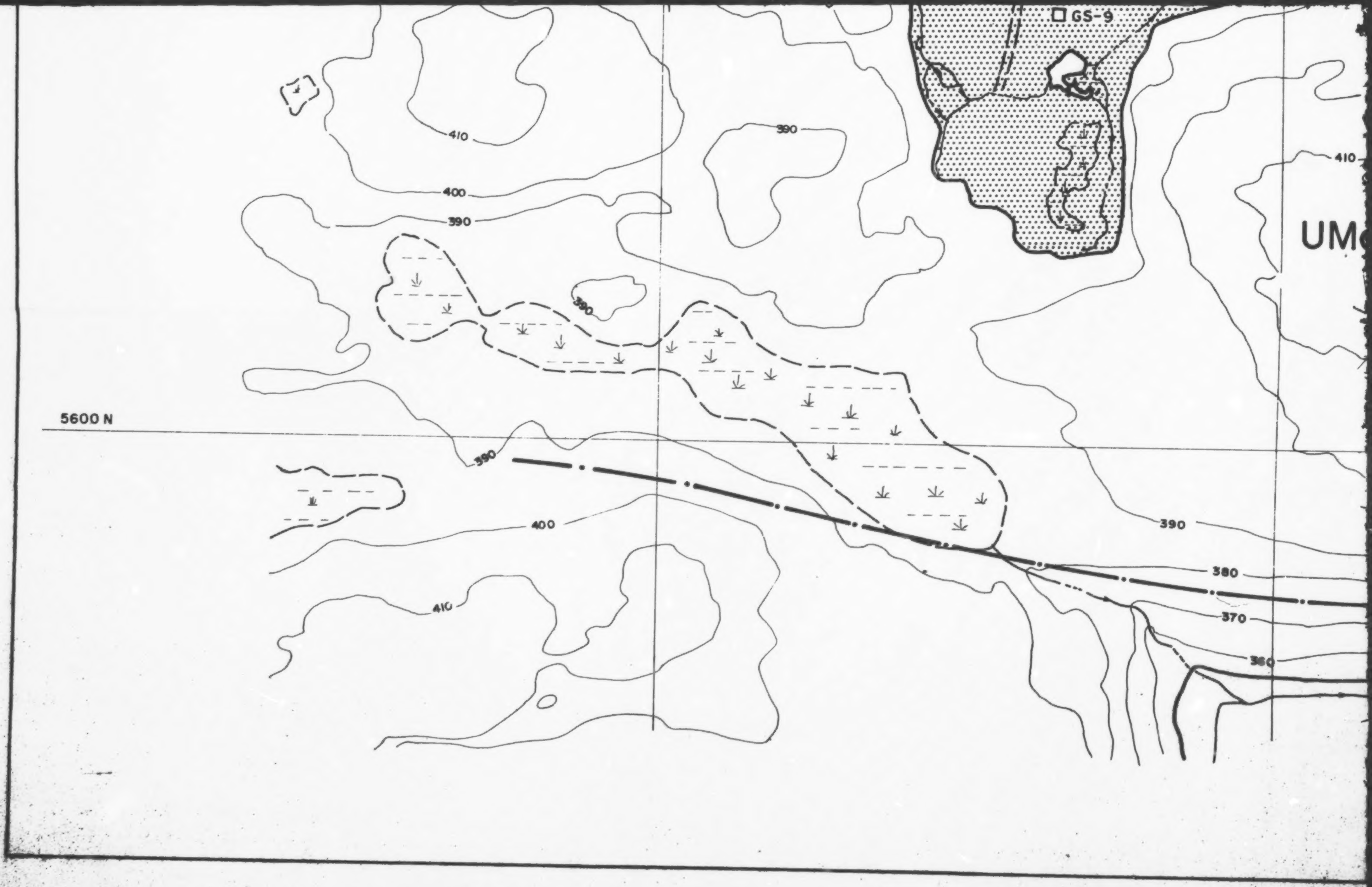
FAULTS; MAJOR, MINOR

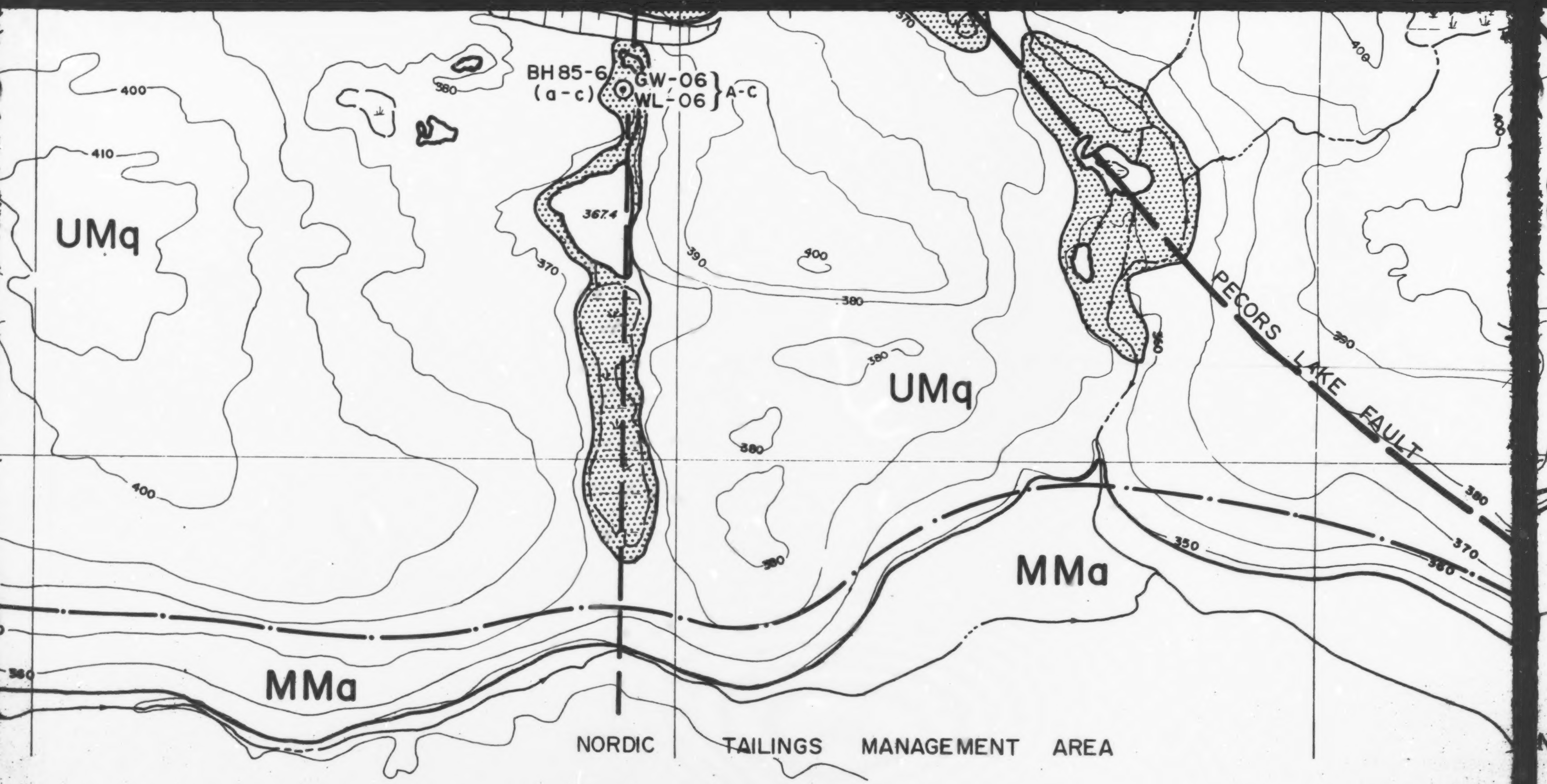
GEOLOGIC CONTACT

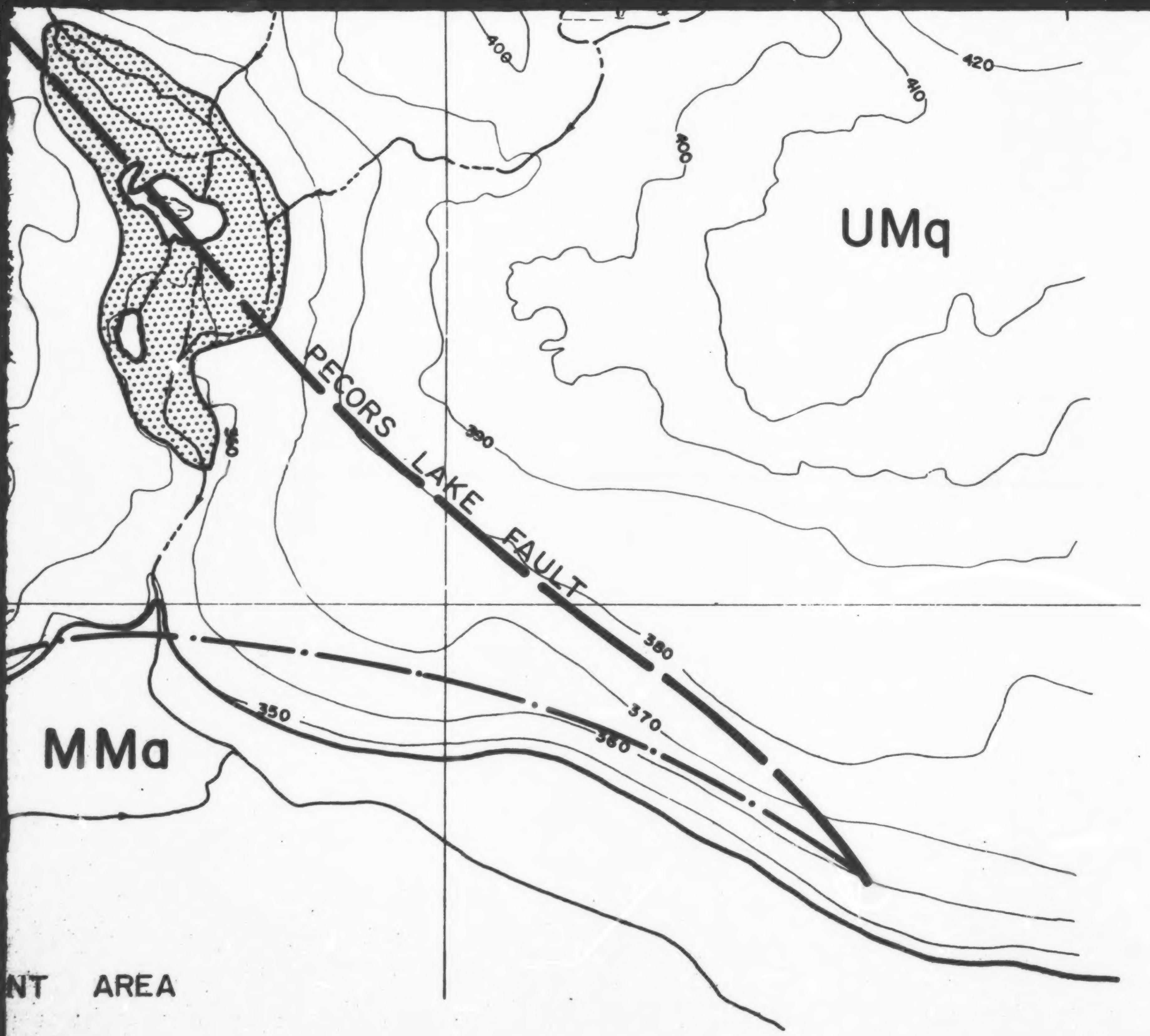
LOWER PROTEROZOIC

Nd	NIPISSING DIABASE, DARK GREEN, FINE TO COARSE GRAINED, DIABASE COMPRISED OF OPHITIC TO GABBROIC TEXTURED PLAGIOCLASE AND PYROXENE
UMq	UPPER MISSISSAGI FORMATION, LIGHT GREY TO PINKISH GREY, FINE TO MEDIUM GRAINED, MEDIUM TO THICKLY BEDDED, FELDSPATHIC QUARTZITE
MMq	MIDDLE MISSISSAGI FORMATION, LIGHT TO DARK GREY, THINLY TO MEDIUM BEDDED, INTERBEDDED DOLOMITIC ARGILLITE AND QUARTZITE

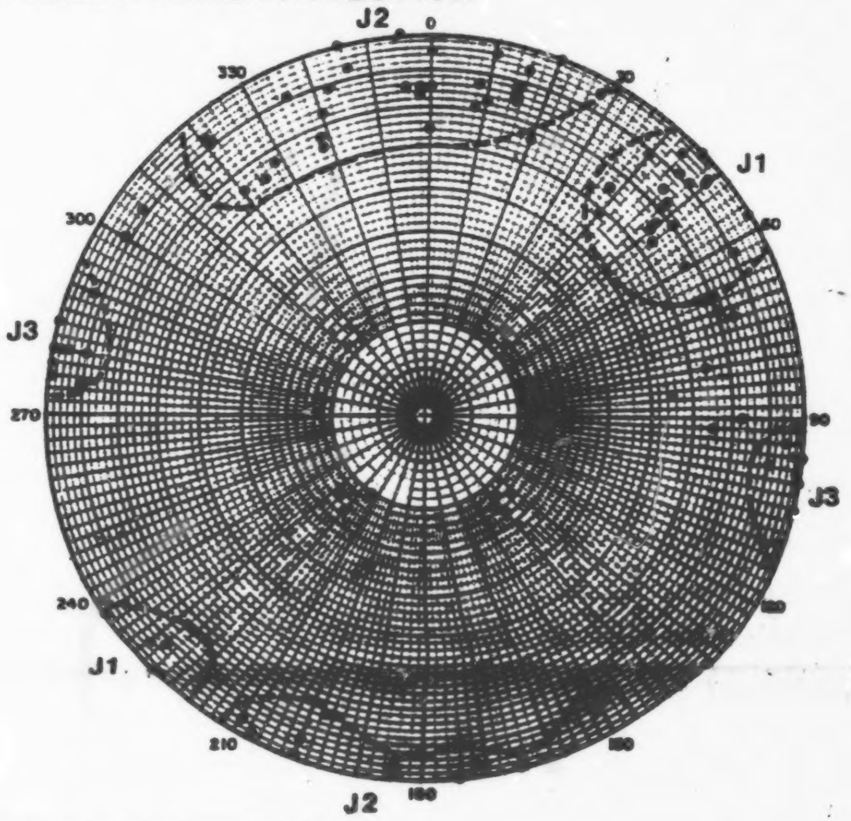
POLAR EQUAL AREA STEREONET :
LOWER HEMISPHERE PROJECTION


GS-9
410
390
400
390
390
410
UMc
5600 N
390
400
410
390
380
370
360


BH85-6
(a-c)
GW-06
WL-06
A-C
UMq
UMq
367.4
400
410
400
380
370
390
400
380
380
380
380
380
400
400
360
390
380
370
380
350
360
PECORS LAKE FAULT
MMa
MMa
NORDIC TAILINGS MANAGEMENT AREA


400
420
410
400
UMq
PECORS LAKE FAULT
390
380
370
360
350
MMa
NT AREA

POLAR EQUAL AREA STEREONET :
LOWER HEMISPHERE PROJECTION


J2
0
30
330
J1
60
300
J3
270
90
J3
240
120
J1
210
150
J2
180

JOINT DISCONTINUITIES

J1 — JOINT SET DIPPING 60 TO 90 DEGREES TOWARDS THE SOUTHEAST

J2 — JOINT SET DIPPING 60 TO 90 DEGREES TOWARDS THE SOUTH

J3 — JOINT SET DIPPING 80 TO 90 DEGREES TOWARDS BOTH THE EAST AND WEST (CONJUGATE)

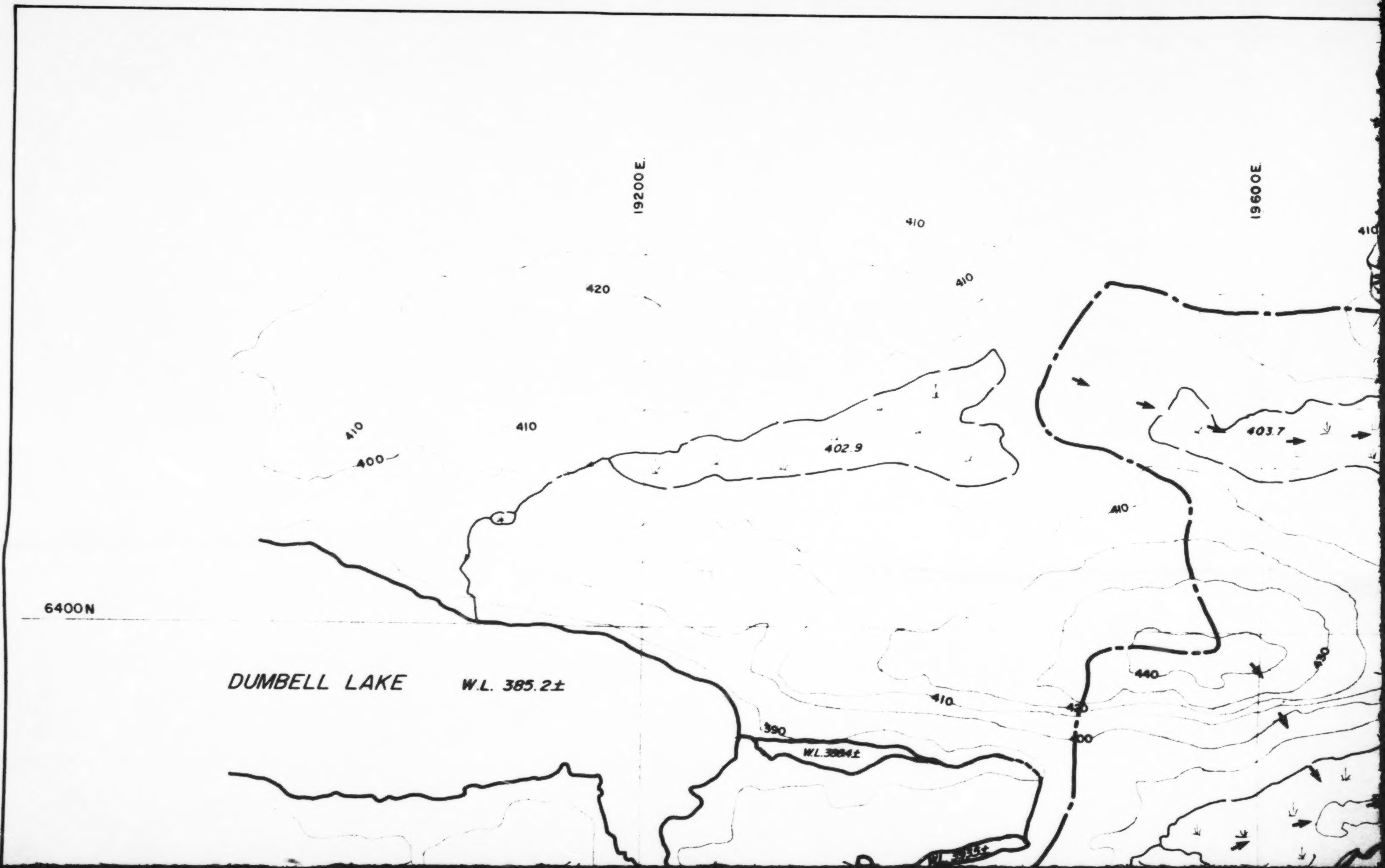
0 50 100 200m

SCALE 1 : 2000

Date [illegible]
Project [illegible]

Golder Associates

[illegible]


19200 E.
19600 E.
410
420
410
410
410
400
402.9
403.7
410
6400 N
DUMBELL LAKE
W.L. 385.2±
410
440
430
420
400
390
W.L. 388.4±

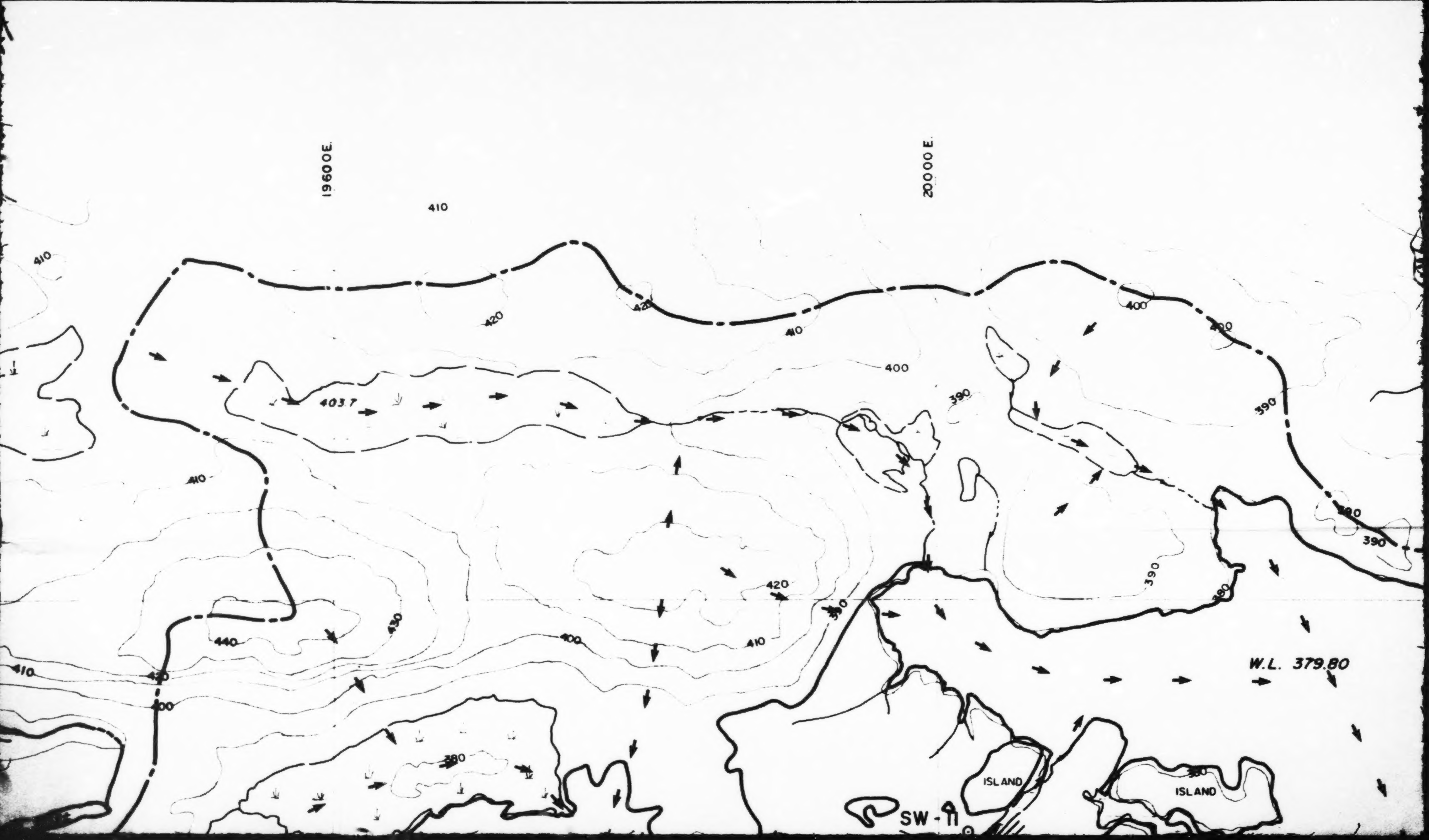
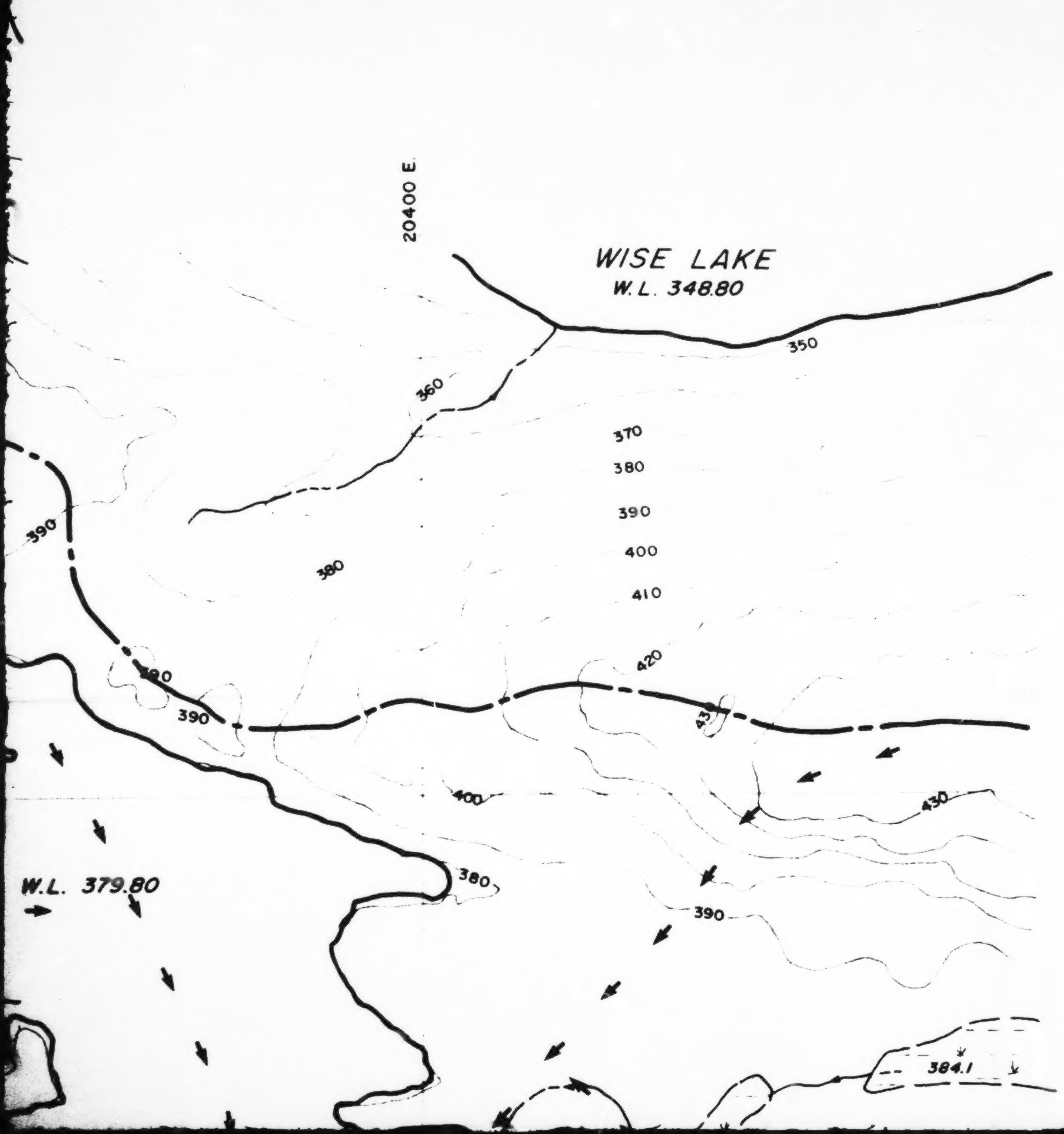

19600E.
20000E.
410
410
420
420
410
400
400
390
390
390
403.7
410
420
430
440
420
400
400
410
390
390
390
390
380
380
ISLAND
ISLAND
W.L. 379.80
SW-11

FIGURE 3.1

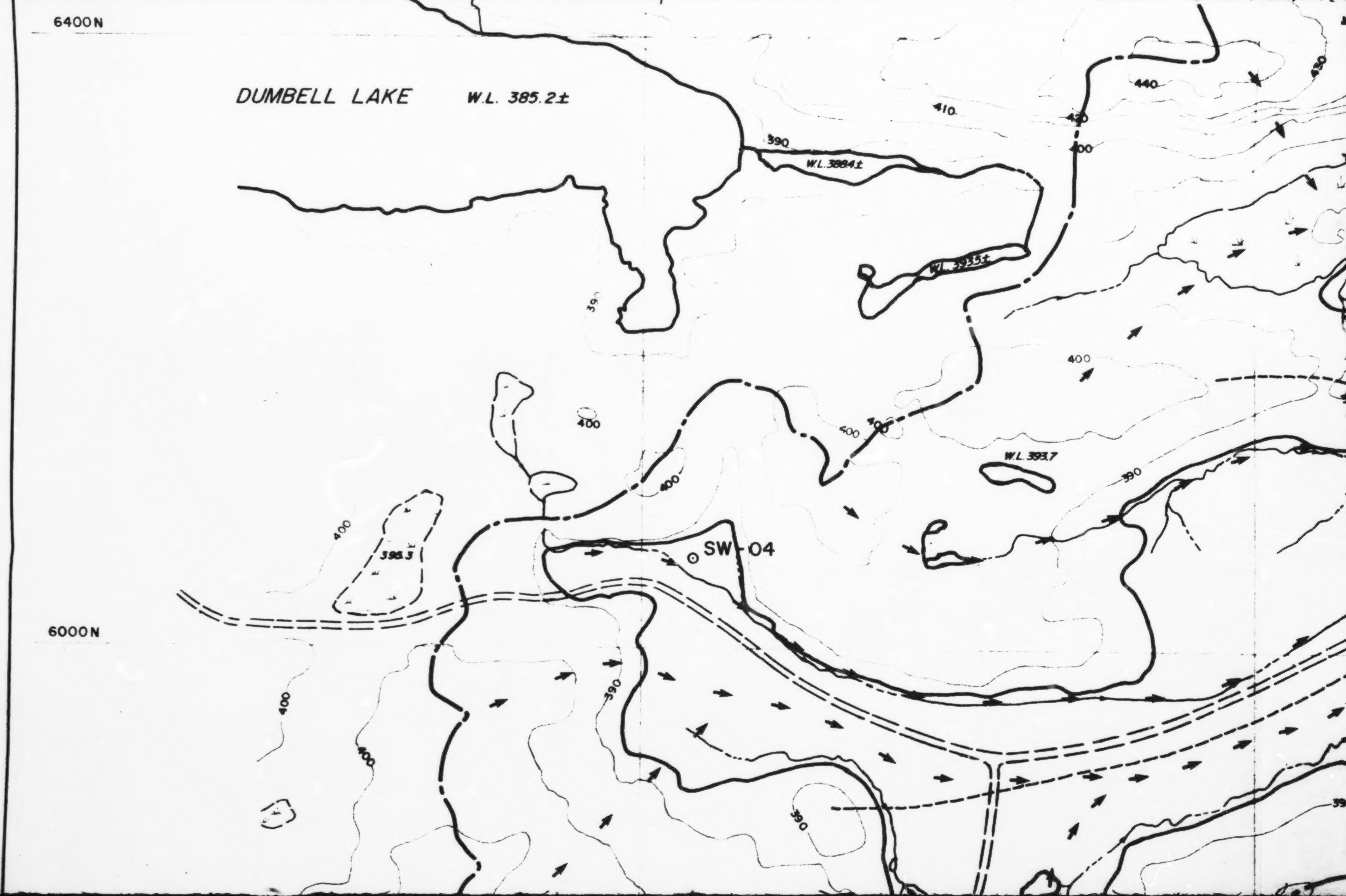
SURFACE WATER

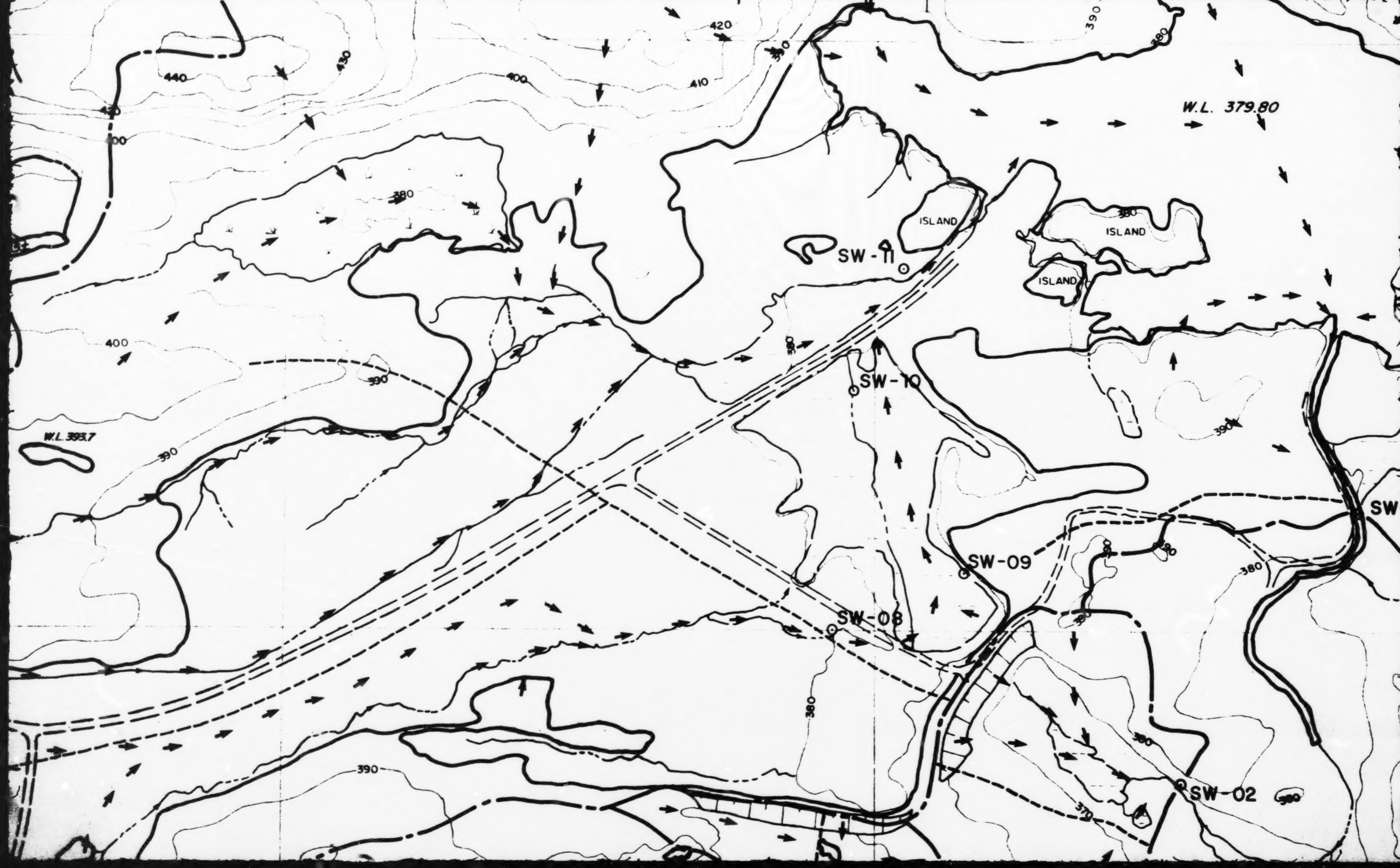
MICRO DRAINAGE PLAN AND LOCATION OF SURFACE WATER GAUGING STATIONS

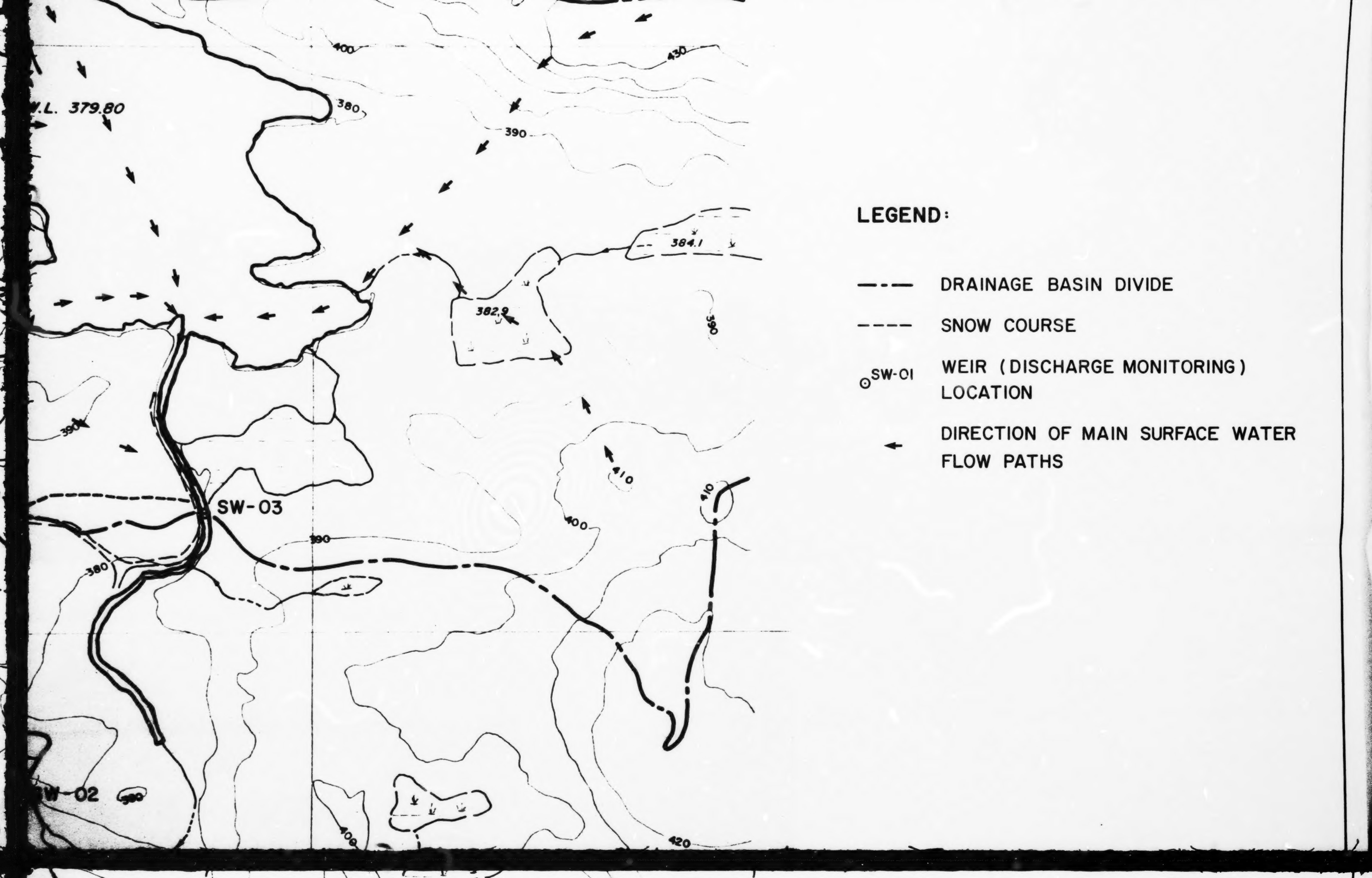

20400 E.
WISE LAKE
W.L. 348.80
350
360
370
380
390
400
410
420
390
380
390
390
43
400
430
380
390
W.L. 379.80
384.1

LEGEND:

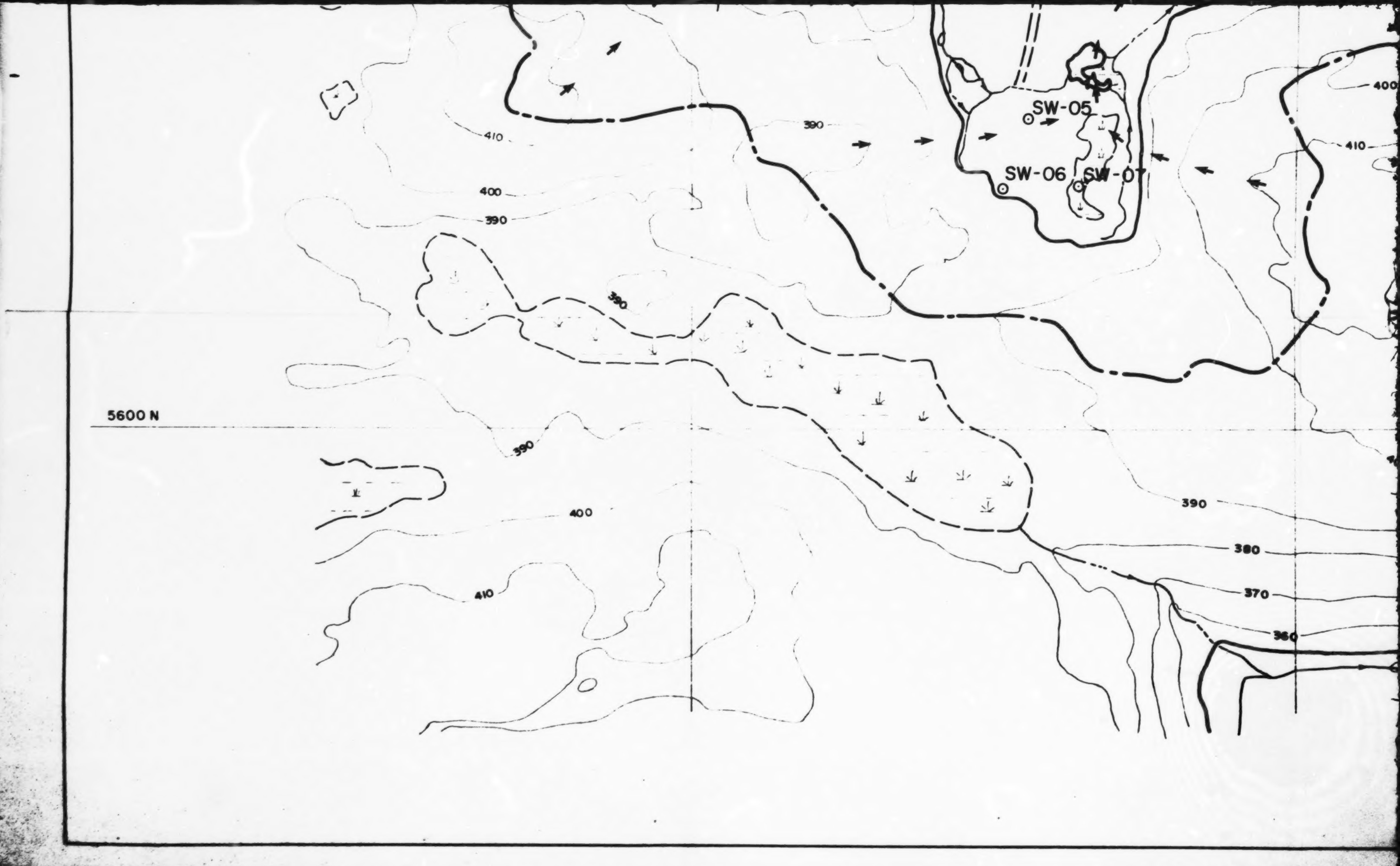
—·— DRAINAGE BASIN DIVIDE

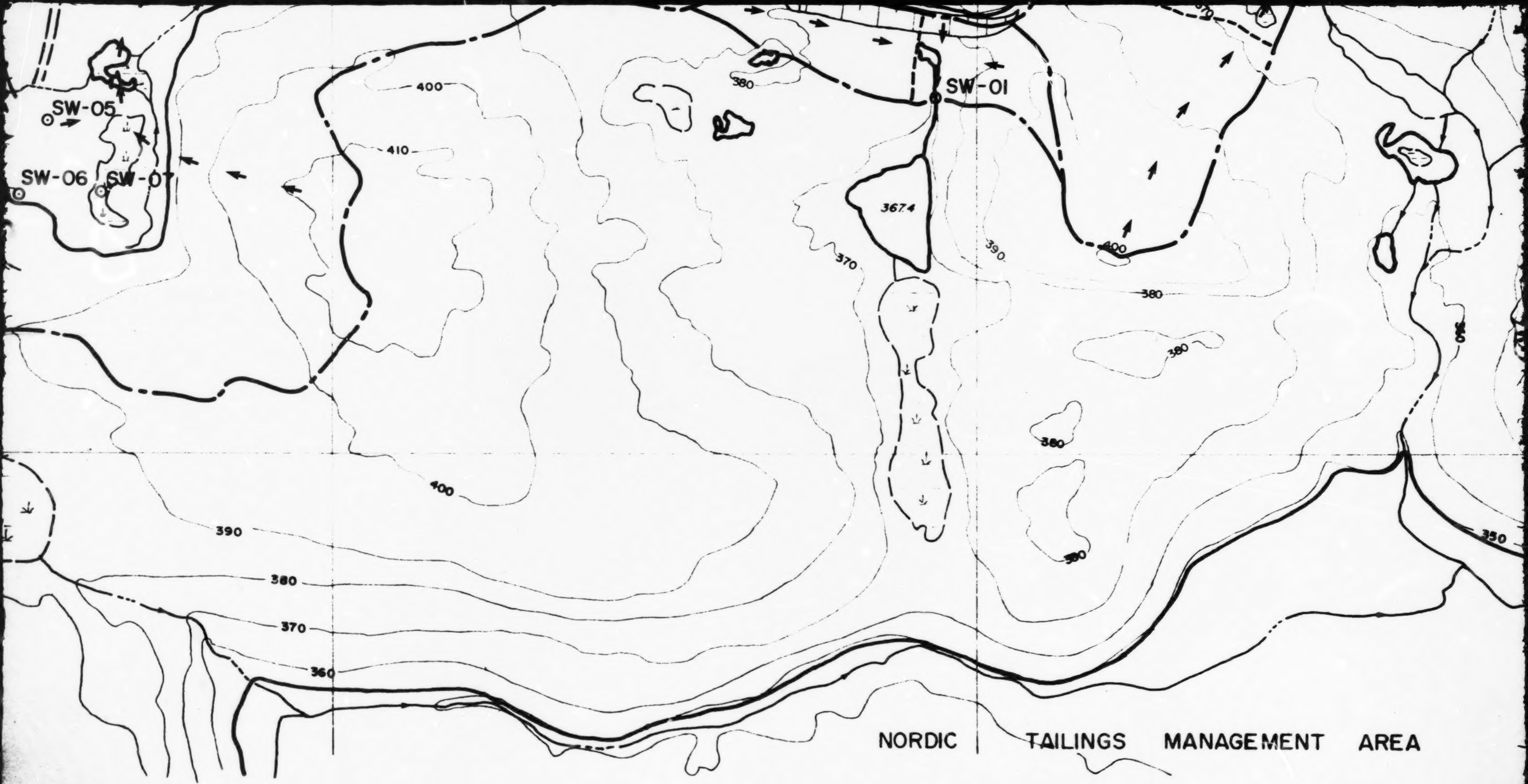

6400N
DUMBELL LAKE
W.L. 385.2±
390
W.L. 388.4±
410
440
430
420
400
W.L. 393.5±
390
400
400
400
400
W.L. 393.7
390
400
398.3
SW-04
6000N
400
400
390
390

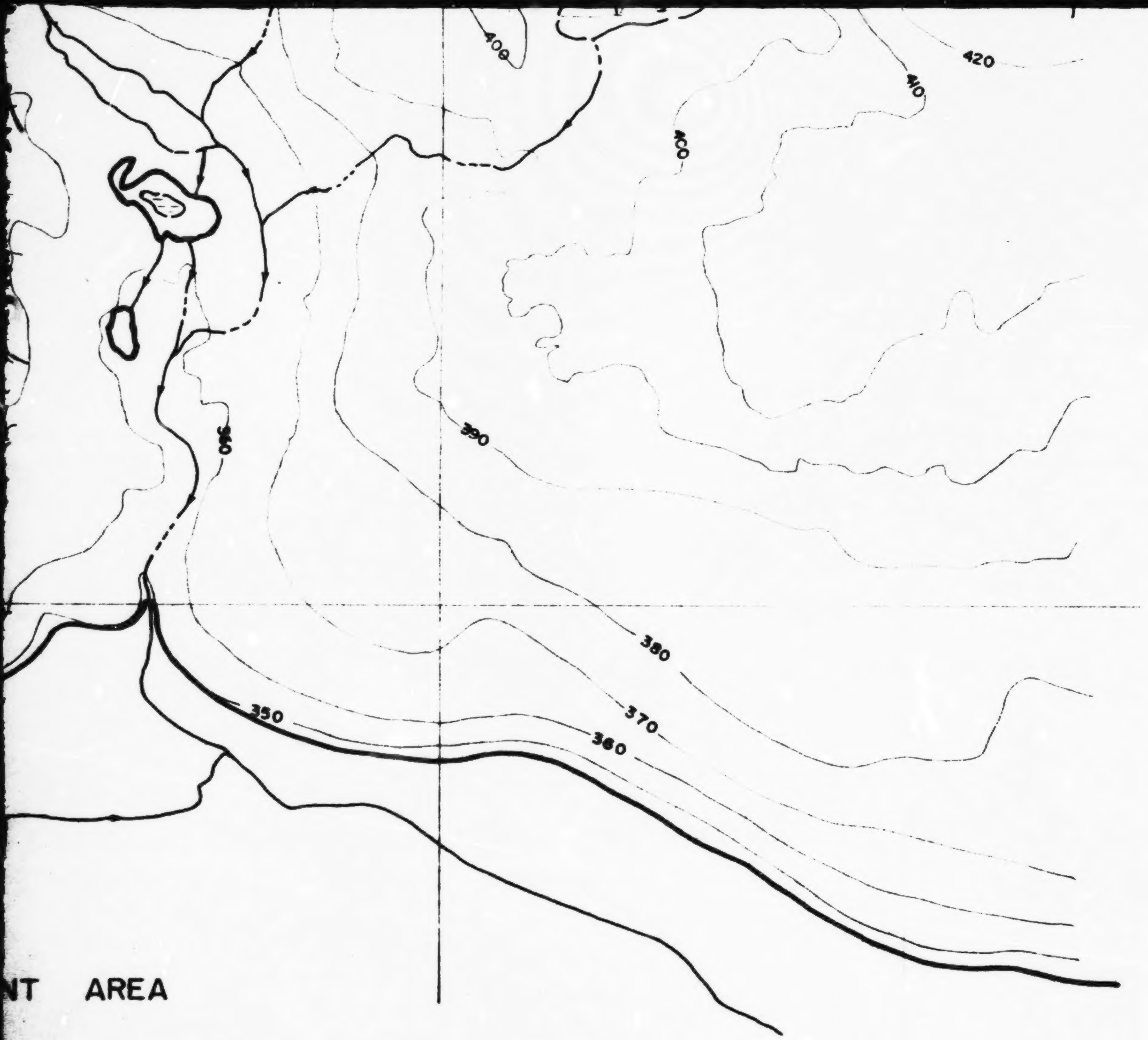

420
440
430
400
410
390
420
400
380
W.L. 379.80
380
ISLAND
ISLAND
ISLAND
SW-11
380
SW-10
400
390
390
W.L. 393.7
390
SW-09
SW
380
380
SW-08
380
380
380
390
SW-02
370
380



W.L. 379.80
400
430
380
390
384.1
382.9
390
390
410
410
400
SW-03
390
380
SW-02
380
400
420
LEGEND:
DRAINAGE BASIN DIVIDE
SNOW COURSE
SW-01
WEIR (DISCHARGE MONITORING) LOCATION
DIRECTION OF MAIN SURFACE WATER FLOW PATHS


410
400
390
390
SW-05
SW-06
SW-07
400
410
390
5600 N
390
400
410
390
380
370
360


SW-05
SW-06
SW-07
SW-01
400
410
380
367.4
370
390
400
380
380
380
380
380
400
390
380
370
360
350
390
NORDIC TAILINGS MANAGEMENT AREA


400
420
410
400
360
390
380
370
360
350

NT AREA

0 200 m

SCALE 1:2000

BEAK CONSULTANTS
CUMMING - COCKBURN & ASSOCIATES